SPEECH PRIVACY IN BUILDINGS FOR GENERAL MEDICAL PRACTICE, WITH PARTICULAR REFERENCE TO INDUSTRIALIZED CONSTRUCTION.

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CONTENTS

TABLES

FIGURES

FIGURE NO.

Figs.

Figs.

Figs.

ABSTRACT OF THESIS

The aim is to provide architects and specialist advisors associated with the design of health centres and hospital outpatient departments, with a comprehensive and reliable method for the determination of the degree of speech privacy provided in any given set of circumstances. A precise method of prediction is essential when relatively lightweight industrialized components are employed, or where composite partitions are used.

The first part of the study consisted of a critical re-appraisal of previous methods of prediction, coupled with preliminary experiments in the field. This was followed by more precise laboratory experiments to establish specific criteria, for sound insulation in relation to background noise, relevant to both consulting rooms and waiting areas.

Two health centres and the outpatients department of a general hospital, all new buildings, were used for detailed experimental case studies. The latter were carried out to obtain data relating to background noise levels and also, sound insulation characteristics of a special form of metal-faced plasterboard partition. The performance of this partition is compared with that of ordinary plasterboard fixed to metal studs. In addition, extensive measurements were undertaken, in a prototype building, of composite partitions incorporating fire check doors of various weights. The effect of plenum barriers was similarly studied.

The results of all measurements are interpreted using standard grading procedures; further deductions are made regarding the

magnitude of allowances for flanking transmission and absorption characteristics of receiving rooms.

The last part deals with the general planning problems relating to sound isolation in buildings of the type described. A detailed prediction procedure is set out for use by designers. The potential of artificially induced masking noise, as a supplement to existing partitions, was investigated during the course of one of the case studies. A theoretical technical development of an electronic system of this type is postulated, in addition to detailed developments of the partitioning system.

PREFACE

This research was carried out whilst the author was on secondment to the Scottish Development Department from the Department of Architecture of the University of Edinburgh, and was sponsored in part by the Scottish Home and Health Department. A comprehensive rebuilding programme for hospitals has been in operation since the inception of the National Health Service and attention is now being focussed upon the provision of accommodation for the general practitioner. The prime function of the health centre and also the hospital outpatient department is to provide a suitable environment in which the doctor can consult with and examine his patients. There is an obvious need for both visual and aural privacy and the collective experience of the S.D.D. and S.H.H.D. indicated that of these two requirements that of aural privacy is the most difficult to satisfy, particularly if communicating doors are required between consulting rooms.

The original hope and intention was to undertake a comprehensive series of laboratory experiments to effect a theoretical re-appraisal of sound insulation criteria which may be applicable. This would have formed the nucleus of the research programme and results might have been correlated with a user survey to establish whether the predictions made as a result of the laboratory experiments were valid. As the work progressed however circumstances brought about a radical change of emphasis. It became clear that not only was there a lack of specific criteria on insulation standards but also that the information available as a base for decision making was either inaccurate or prone to misinterpretation. The need to bridge the gap between building scientist and architect became of prime importance.

The Rothschild report[1] was produced at the same time that this research was getting under way, and also influenced this redirection from a more theoretical approach to one which was capable of direct implementation. In a situation of this kind the question of speed of feedback is crucial, the essential thing being to acknowledge that the interim research findings must be fed into the development programme as quickly as possible before all major decisions are taken with regard to the buildings forming the bulk of the programme. To pursue the alternative course usually means that the results of the research, however sophisticated, arrive too late to have any appreciable influence. This must of course apply to all applied research and is concordant with the spirit if not the words of the Rothschild report.

Whilst many health centres and associated buildings are of traditional construction there is an increasing tendency towards the use of more industrialized methods to accelerate the rate of completion. The most widely adopted system in Scotland is that initially evolved by the Consortium of Local Authorities Special Programme (CLASP) in Nottinghamshire.[2] An initial feedback resulting from the first stages of the research findings to the use of this and similar forms of construction suggested that there was an urgent need for more information as to the way in which the CLASP system performed in the field. A subtantial part of the study was therefore redirected to this end, with the result that the time spent on laboratory work was proportionally reduced. Nevertheless, although many limits were imposed by these practical considerations many benefits also accrued. Money and resources became available to enable modifications to be made to what were in effect prototype buildings during the final stages of completion; the efficacy of remedial measures could be established under more or less controlled conditions.

The need to bridge the gap between architects and scientists has already been mentioned. The corollary is that research findings in this field must be presented in a form suitable for assimilation by both. A glossary of terms is included for the benefit of the reader who is not scientifically orientated but this may of course be redundant for those who are. On the other hand some of the definitions provided in relation to architectural terminology and specifications may be useful to the scientist or technician. Similar considerations also apply to many of the statements in the main text.

The author gratefully acknowledges the support, financial or otherwise, given by the S.D.D., the S.H.H.D. and the Western General Hospital Board, the advice and encouragement from Professor Sir Robert Matthew, Mr. Bruce Beckett, Chief Architect to the S.D.D., Professor Guy Oddie, Head of the Department of Architecture, University of Edinburgh, Professor Peter Lord, Department of Pure and Applied Acoustics, University of Salford and Miss Justin Blanco-White, the Superintending Architect responsible for the administration of the research contract. Dr. Don McCreadie of the S.H.H.D. and Charles Hope, Dr. John Gibbons, Kate Sharpe and Alistair Jack of the S.D.D. provided many helpful comments during the course of the work, the last also being responsible for the preparation of detailed drawings and specifications essential for the Paisley experiments. John Evans of the Hospital Board helped with the supervision of the actual

construction work at Paisley and David Parker as Senior Technician undertook many field measurements under the author's direction.

I INTRODUCTION

1.1 General.

If a satisfactory aural environment is to be achieved criteria must be established to deal with various aspects. The function of each room can be examined to determine both the level and nature of sounds generated within it and the noise sensitivity of occupants. A limit is then selected with a view to keeping the general ambient noise from interfering unduly with speech. In addition, an adequate amount of insulation will be required between rooms, to provide speech privacy and to ensure that noises of an intermittent character do not become too distracting, particularly when concentration is called for. An optimum range of conditions is thereby indicated; the sound insulation required depends not only upon the level and character of speech in the adjacent room (which itself may relate to the ambient noise in that room), but also upon the ratio of the speech level coming through the partition to the ambient level in the receiving room.

Substantial variations in speech level can occur depending upon the individuals involved in the consultation. If a patient is discussing something of a particularly confidential nature he may instinctively lower his voice. At the other extreme a deaf patient can cause the doctor to shout, or at least raise his voice to a very loud level. Similarly such factors as sex of speaker, rate of speech and accent affect the degree of comprehension of the listener.

1.2 Major aspects and constraints: the design problem.

From the architect's viewpoint the problem could be easily solved, if there were no financial or other constraints, by selecting a construction of very heavy traditional material and thereby providing a reasonable safety margin. Usually however, numerous other complications arise to confuse the decision making process.

Several studies have been carried out which deal with the overall planning and detailed functional requirements of health centres and hospital outpatient departments. Reference to these indicates that in England the health centre tends to be smaller with consulting room layouts similar to those used for the more traditional group practice.[3,4] In Scotland the trend has been toward the creation of larger centres containing more extensive facilities. In these larger buildings intercommunicating doors are provided between consulting rooms, designed to encourage the use of suites of rooms by visiting specialists for clinics and similar activities. A decision must then be taken whether to provide double doors (which may be inconvenient), or alternatively to use a special form of single door.[5]

Similar complications arise from the use of lightweight industrialized building systems, especially if suspended ceilings and plenum spaces are designed to accommodate services. This is a common practice. In such cases consideration must be given not only as to whether the basic partition is adequate, but also to the necessity for incorporating a plenum barrier or upgrading the suspended ceiling.

A loss of speech privacy may be found in buildings of either lightweight industrialized or traditional heavy masonry construction, with or without communicating doors, suggesting that a need exists to provide architects and others associated with design policy, with a comprehensive, reliable and easily used method for evaluating and integrating the numerous variables involved. Many methods have been postulated dealing with this type of acoustic problem and, data exists for a wide range of constructions. Upon close examination however some essential step or item of information is lacking. Some methods emphasise the importance of the general noise climate and suggest how the insulation requirements can be determined if the noise climate is known, but fail to provide any means by which the latter may be predicted. Others omit such significant factors as flanking transmission. In many instances data is obsolete or the test conditions are not explicit and the architect does not know which correction factors to apply. Numerous research papers exist which treat specific aspects in great detail, but the practitioner has neither the time nor the expertize to extract and integrate the relevant information.

In broad terms the analytical approach may be structured thus :-

> Firstly, suitable criteria must be established to describe the degree of insulation required and the limits to background noise in all major areas of the building; secondly, reliable data relating to both the ambient noise and to the form of construction under consideration must be assembled; and finally, a method must be selected to enable the designer to comprehend the factors involved, to assess the magnitude and variability of each, to understand the complex interactions and, to arrive at a final decision.

1.3 Existing standards and methods of prediction.

Recommendations regarding a performance standard for sound insulation between the doctors' surgeries are contained in British Standard

Code of Practice CP3 Chapter III (1972) which states:-

> Apart from the general problem of disturbance from outdoor noise a common problem in doctors' surgeries is the transmission of sound between the consulting room and the waiting room. To ensure privacy a sound reduction between the rooms of 45 dB should be provided if possible (e.g. 112.5 mm brick wall, plastered) and certainly not less than 40 dB (e.g. 75 mm clinker block wall, plastered). If the rooms are directly connected by a single communicating door it will not be possible to achieve those levels of insulation. To obtain 40 - 45 dB insulation between communicating rooms it is necessary to provide two doors separated by an airspace such as a lobby or corridor.

This standard and the position regarding surgeries in general were discussed by Allen in a symposium held in 1961;[6]

> It is not so necessary to satisfy personal feelings as to avoid some specific fault such as revealing intelligible information, or preventing possibly troublesome interference.
>
> A doctor's surgery is an instance of the former and, despite the fact that as a building type it is scarcely prominent, it has been a very common cause of noise complaints. A medical discussion with a patient should not be intelligible either in the corridor outside his office or in the waiting room or ante-rooms, and for this purpose an insulation of 45 dB is recommended and 40 dB is said to be the minimum acceptable. A considerable number of complaints have been received at the Building Research Station over many years and form the background to the standard. Recommended treatments often appear successful, but field measurements are again lacking.

The same British Standard also draws attention to the importance of ambient noise in assessing the degree of sound insulation required in any given set of circumstances:-

> Background noise and masking. Background noise is the more or less continuous noise present due to internal activities or to unavoidable but familiar intruding noise such as traffic noise. The effect is to mask other sounds. Very often of course the masking noise interferes with the communication of speech or music and is a nuisance, but there are also times when the insulation of particular noises is desired and then the partial masking of those noises by accepted background

> noise is an advantage. The background noise in effect adds to the insulation by raising the threshold at which the unwanted noise begins to be heard or noticed.
>
> The practical effect of masking background noise is quite important. For instance, less insulation between rooms will suffice in town buildings subjected to continuous traffic noise than in quiet country buildings. But it must be borne in mind that if the traffic noise were to be excluded from the town buildings, say by putting in double windows, then the occupant would at once become more sensitive to internal noise, the same conditions being obtained as in the country building. The actual allowance that can be made for the masking effect of background noise must actually be a matter of experience so far as general problems are concerned.

Although BS CP3 does not give specific information as to the effect of background noise some textbooks dealing with building acoustics provide nomograms or tables which account for masking. Recommendations for masking noise levels in hospitals are made by Rowlands et al,[7] following extensive field measurements. Two of the more recent textbooks[8,9] draw attention to a detailed method based upon 1/3 octave band analysis originally proposed by Cavanaugh et al[10] in the U.S.A. and a single number rating system derived from their work by Young.[11]

1.4 Preliminary visits to existing health centres.

In the preliminary stages of this research, steps were taken to corroborate the standards and predictive methods described in previous paragraphs. Several new health centres had been completed in Scotland (of traditional construction) and acoustic problems were being raised by occupants. Visits were paid to these buildings,[12] together with a number in England of both traditional and non-traditional construction.[13] The purpose of the visits was twofold; firstly, to discover how widespread was the dissatisfaction with regard to insulation and secondly, to contact the administrative officers of the buildings concerned.[14] The ultimate object was to gain their co-operation in carrying out a survey to establish the responses of doctors and patients to their acoustic environment. Discussions with the latter were avoided so as not to contaminate results of future surveys. The administrative officers, by the nature of their job, were fully aware of any comments already put forward by the occupants of the buildings.

Some of the points raised in these discussions are referred to in Chapter VII. One salient point which emerged and which is relevant in the present context, is that although the CLASP Mk 4B system was used in three of the health centres there was no obvious dissatisfaction with sound insulation in these buildings. (The exception, which was noted in only one location, appeared to be due to flanking transmission through ventilation ducts.) This general conclusion was surprising, as the average airborne sound insulation of the CLASP Mk 4B system was believed to be substantially below the 40 dB minimum of BS CP3.[15]

1.5 Field trials.

To gain further insight field trials were set up in two locations. The first of these was held in the new outpatients department at Falkirk Royal Infirmary during the final stages of completion.[16] The partitions between consulting rooms incorporated very heavy flush doors fitted with double Neoprene seals, in a standard form of plasterboard partition. The airborne sound insulation for this configuration had been measured at 31.7 dB with an Insulation Index of 36 dB (for further details see test series C, Chapter IV).

The experimental procedure adopted for these trials was as follows:-

A tape recorder, amplifier and loudspeaker were placed in the consulting room and the three subjects (an architect, a senior executive doctor and a senior executive nurse, all with considerable experience in outpatient department design), were asked to listen to a tape recording (standard dictation tape, 120 words per minute, male speaker)[17] and agree a reference voice level. This was subsequently measured at several points and averaged 59 dBA. The subjects were then asked to move into the adjacent consulting room and given the form shown in Fig 1.1. They were asked to judge the degree of sound insulation for each experimental condition and mark the appropriate box. The semantic categories used were similar to those originally adopted by Cavanaugh et al.[18]

The simulation was carried out by previously calibrating the amplifier gain control as shown in Table 1.1 to reproduce various conditions in steps; these conditions were distributed around the standard one i.e. that which actually existed. The reproduction could only approximate as the shape of the insulation spectrum could not be varied but was dictated by the composite spectrum of the reference partition and door. Conditions 1 - 4 were judged against the natural ambient noise level measured at the beginning and end of the experiment at 26 dBA (L_{50}). In conditions 5 & 6 artificial ambient noise was introduced using the spectrum of Fig 1.2, without informing the subjects, the source being prerecorded on channel two of the tape recorder and played back through two small speakers concealed behind the window curtains. These artificial ambient levels were set at 42.5 and 47.5 dBA respectively.

Responses. - Level of satisfaction with condition of speech privacy.

CONDITION NO.	1	2	3	4	5	6	7	8	9
Very satisfied					✓	✓			
Satisfied							✓		
Mildly dissatisfied			✓	✓				✓	✓
Moderately dissatisfied	✓	✓							
Strongly dissatisfied									

Location of trial ;	Dumbarton Health Centre.
Name of Respondee :	A.N. Other.
Response set no:	2 Date 18.1.73

FIG 1.1 SIMULATION OF VARIOUS SOUND INSULATION CONDITIONS - TYPICAL RESPONSE FORM.

	CONDITION REPRODUCED	EQUIVALENT INSULATION (AVERAGE) dB.	REMARKS	STANDARD SPEECH LEVEL (& ADJUSTMENT)
1	Standard door with single seal.	27.6		59 (+9.5)
2	Standard door with double seals.	30.1		59 (+7.0)
3	Very heavy door with double seals.	33.1		59 (+4.0)
4	Plasterboard partition with no door, alternatively Mk 4B with double door.	37.1	STANDARD CONDITION	59
5	Mk 4B without doors.	41.1		59 (-4)
6	As condition 5 but with masking noise.	41.1	Masking level 42 dBA.	59 (-4)
7	As condition 4 but with masking noise.	37.1	Masking level 42 dBA	59 (0)
8	As condition 3 but with masking noise	33.1	Masking level 42 dBA.	59 (+4.0)
9	As condition 2 but with masking noise.	30.1	Masking level 47.5 dBA.	59 (+7.0)

TABLE 1.1. PROCEDURE FOR SIMULATION OF VARIOUS SOUND INSULATION CONDITIONS AT DUMBARTON HEALTH CENTRE. 18.1.73.

N.B. All tests carried out with windows closed.

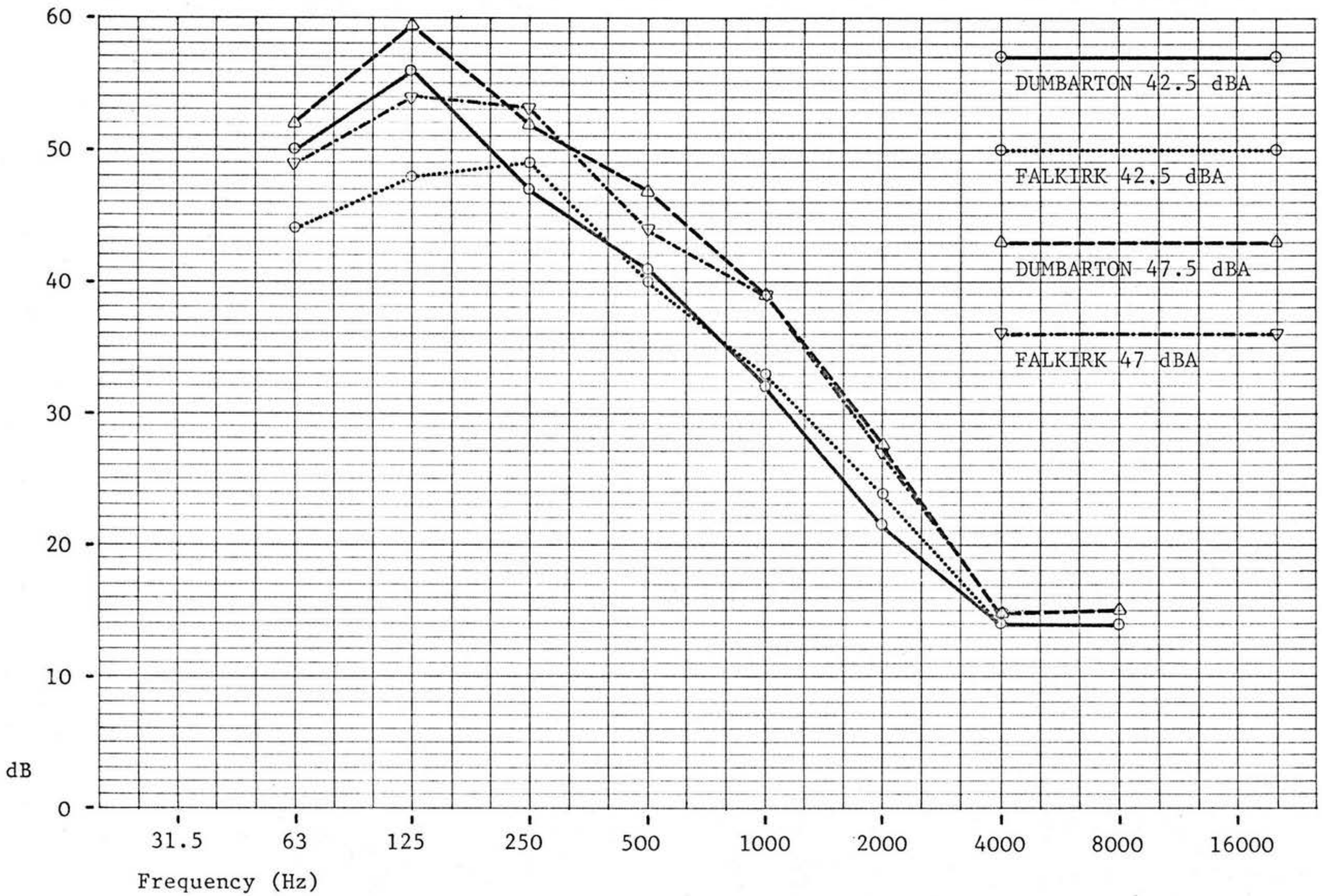


FIG. 1.2 SPECTRAL ANALYSES OF ARTIFICIAL MASKING NOISE USED IN FIELD TRIALS.

The second and third trials were held in the new health centre at Dumbarton,[19] again prior to completion. The form of the experiment was similar to the one held at Falkirk except that the actual reference insulation condition was different (in this case a CLASP 4B partition, fitted with double doors), the average insulation being 37.1 dB (Insulation Index R' - 42 dB). Two reference speech levels were used, namely 59 dBA (normal voice) and 64 dBA (raised voice). Five subjects took part (four architects, all with wide experience in buildings of this type and one clerk of works). Ambient noise measured before and after the test sequence was 36 dBA (L_{50}). The total number of test categories was increased to five for natural ambient noise and four for artificial masking noise.

Linear regression lines for the three trials are shown in Figs 1.3a, 1.3b and 1.3c.

The regression analysis of the Falkirk trials shows that the mean Satisfaction level is reached when 31.6 dB of insulation is provided. (The equivalent Insulation Index Ia is 36.) The regression line cuts the mean Very Satisfied criterion level at 34.7 dB (Ia rating 39). The product moment correlation coefficient (r) is 0.87 and the standard error 0.047.

A similar analysis of the first of the Dumbarton trials yields a mean Satisfaction level of 34.0 dB (Ia rating 38). In this instance the correlation coefficient is 0.89 and the standard error 0.023. Equivalent values for the second trial in the same building are:- mean Satisfaction level 41.9 dB (Ia rating 46), correlation coefficient 0.77, standard error 0.032.

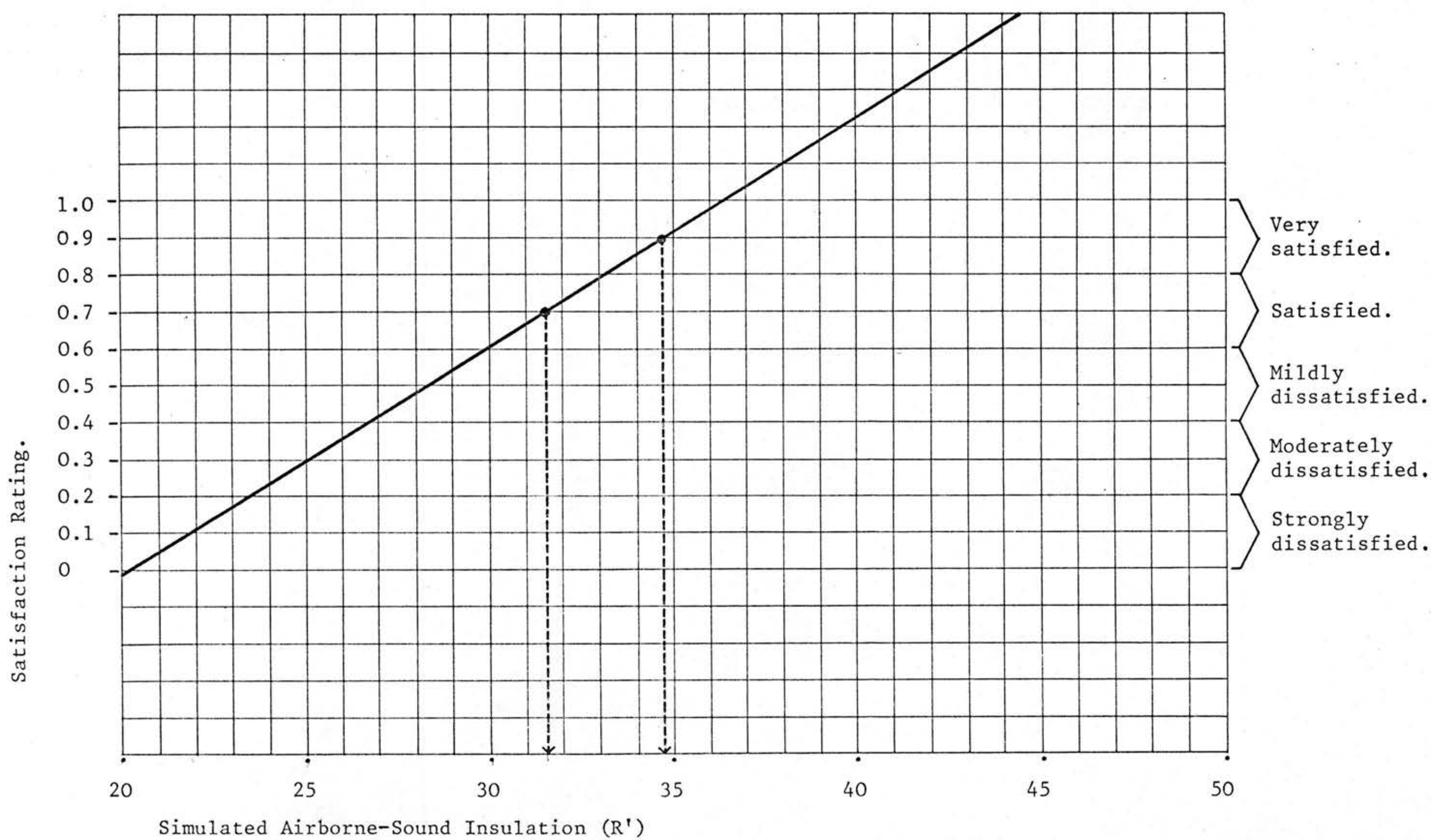


FIG 1.3a LINEAR REGRESSION ANALYSIS OF RESPONSES TO FIELD TRIALS - THE OUTPATIENTS DEPARTMENT OF FALKIRK ROYAL INFIRMARY (TRIAL NO 1 - NORMAL VOICE LEVEL).

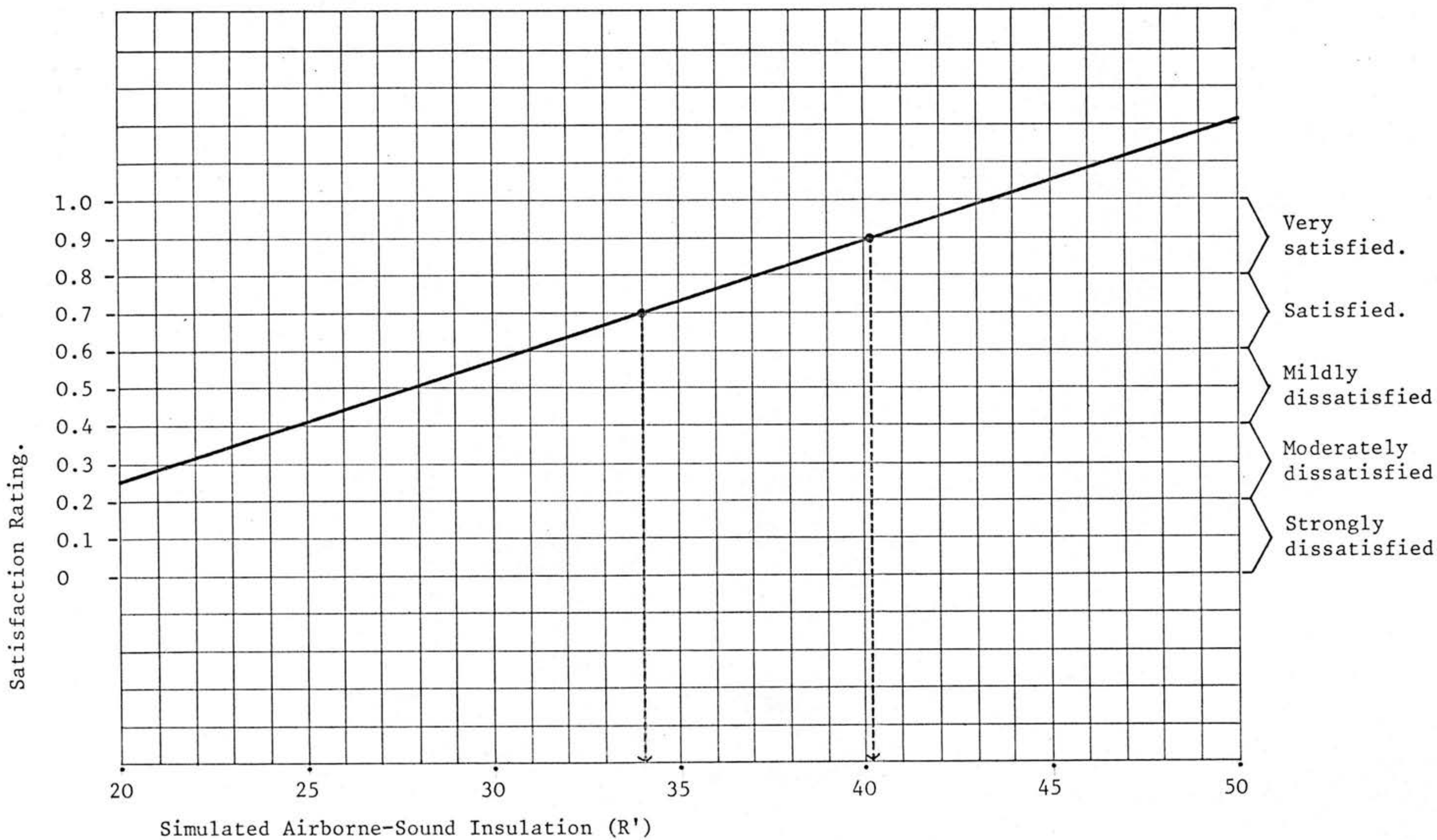


FIG 1.3b LINEAR REGRESSION ANALYSIS OF RESPONSES TO FIELD TRIALS - THE DUMBARTON HEALTH CENTRE. (TRIAL NO 2 - NORMAL VOICE LEVEL.)

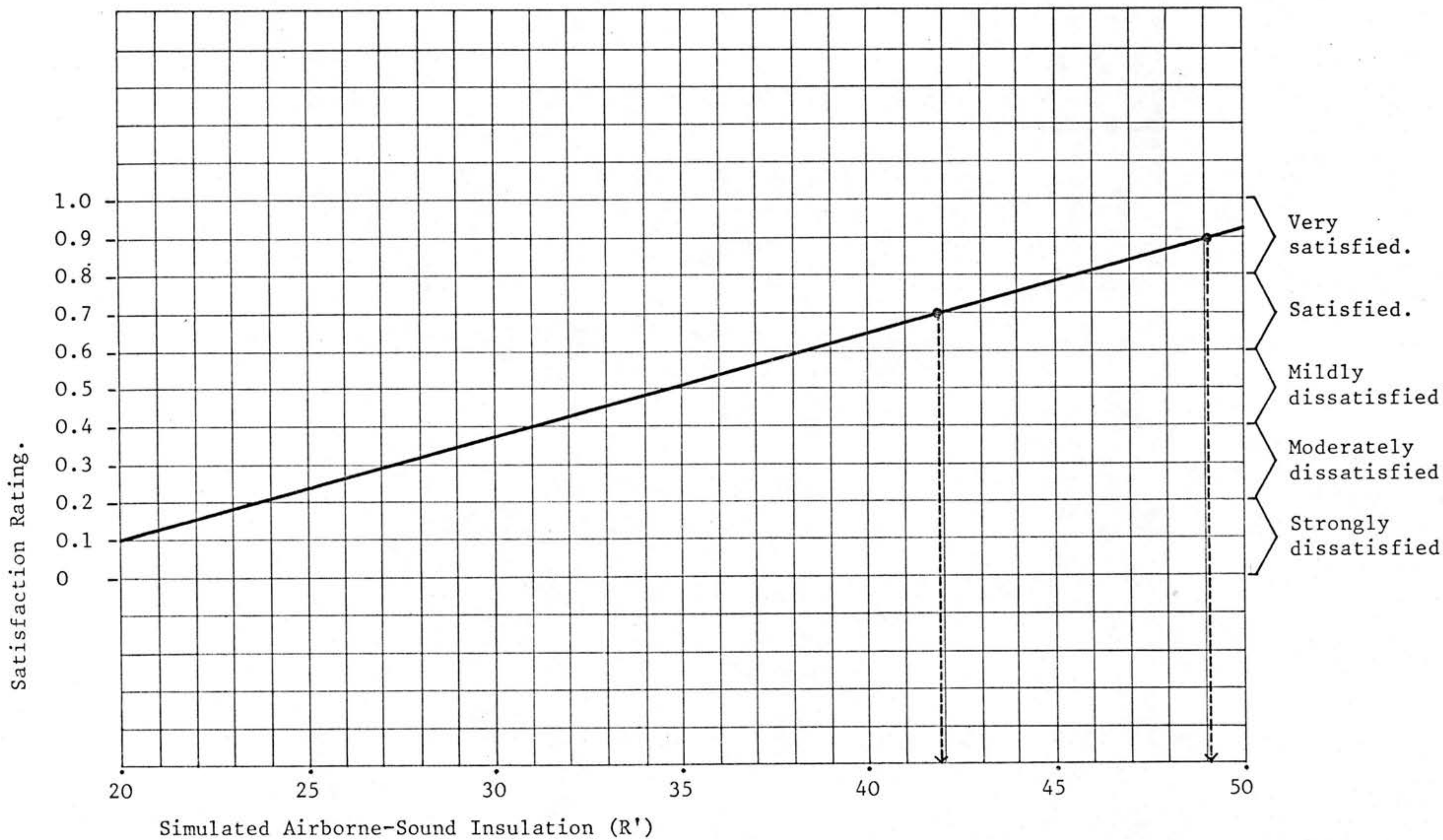


FIG 1.3c LINEAR REGRESSION ANALYSIS OF RESPONSES TO FIELD TRIALS - THE DUMBARTON HEALTH CENTRE (TRIAL NO 3 - RAISED VOICE LEVEL).

The simulated conditions which incorporated artificial masking noise have not been subjected to regression analysis due to the small sample presented to subjects. The responses suggest however that whereas the 42 dBA masking level helps to restore speech privacy and is acceptable to most subjects the 47 dBA level is rejected by the majority.[20]

1.6 Comparison of field trials and existing predictive methods.

It is also interesting to compare the results of these pilot experiments with the prediction following from Young's method[21] for the two buildings in question. In his analysis the following formula is used:-

$$X = S + P + F - (I + K + N)$$

where X = sound excess.

S = average sound pressure level of speech in the source room (take 60 dB for conversational voice, 66 dB for a raised voice and 72 dB for a loud voice).

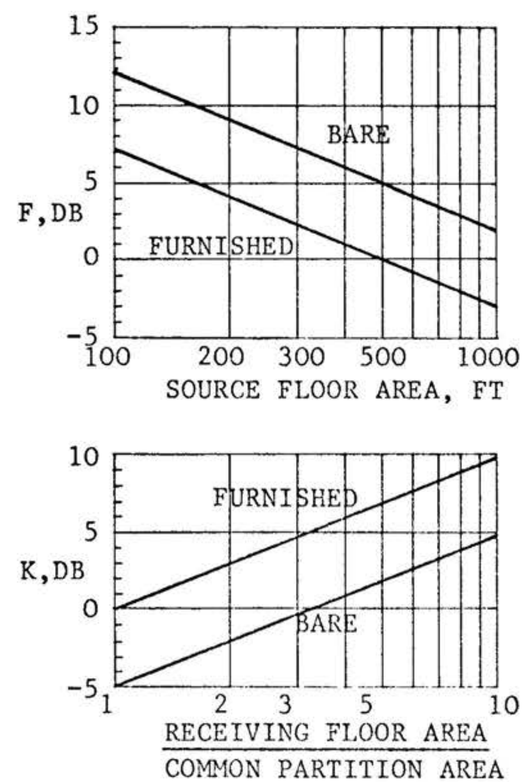
P = degree of privacy required (take 15 for confidential privacy or 9 for normal privacy).

F = correction factor for size and absorption of source room (obtained from graph Fig 1.4a).

I = sound transmission class rating.

K = factor allowing for variations in relative size of common wall and listening room and also for furnishings of listening room (see Fig 1.4b).

N = background noise level in listening room in dBA (if background levels have been specified as NC numbers convert to dBA equivalent by adding 5).



FIGS 1.4a & b Estimates of F and K from room dimensions, for stud-and-plaster construction and room heights of approx. 10 ft.

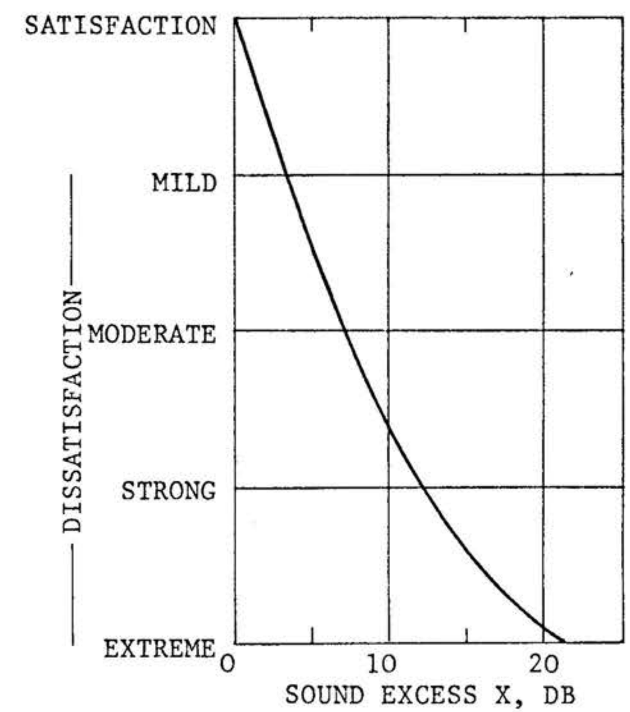


FIG 1.4c Satisfaction with acoustical privacy vs sound excess X.

FIG. 1.4 DIAGRAMS FOR PREDICTING F & K FACTORS, AND RESPONSES (X) FOR YOUNG'S METHOD. a, b & c.

Analyses were made before carrying out the various trials which yielded the following values for X.

Falkirk $X = 60 + 15 + 5 - (36 + 2 + 26) = 16$

Dumbarton $X = 60 + 15 + 5 - (42 + 1.5 + 36) = -0.5$

By reference to Fig 1.4 it may be seen that the prediction by Young's method for Falkirk lies between strong and extreme dissatisfaction, whereas at Dumbarton the prediction is satisfaction. By comparison the results of trials (Figs 1.3a, b and c) show that the reference insulation at Falkirk of 31.7 dB is associated with satisfaction by the regression analysis line A. At Dumbarton the reference insulation of 37.1 dB is associated with the zone (satisfactory/very satisfactory) by regression line B. The forgoing comparisons apply to normal speech levels. Raising the voice level by 5 dB places the regression line for trial no. 3 just within the zone (mildly dissatisfied).

Similar discrepancies were observed by comparison with predictions following the method due to Cavanaugh et al,[22] upon which Young's method is based. This suggests that a critical re-appraisal of such predictive methods is called for, particularly in view of the widespread acceptance which they have gained.

There are a number of possible explanations for the disparities which have been identified in preceding paragraphs. The ambient noise level may be raised from 26 to 35 dBA by the presence of several occupants in a room, or indeed by one occupant, even though an attempt was made during the experiments to keep self generated noises to a minimum. Thus an inverse linear relationship may exist between insulation and masking noise over a limited range of values but could be curvilinear, particularly at the lower ambient noise levels. The subjects used for the trials may not be representative of the population as a whole; alternatively the locations used for the survey quoted by Cavanaugh et al may not be representative of consulting room conditions.[23] Probably the most significant explanation of the discrepancies may be that the speech privacy factor (P) is too conservative, bearing in mind the overall compromise which the architect must make.

1.7 Scope of the present research.

Nevertheless, Young's method and the original research of Cavanaugh et al, represent a valuable contribution to the field under review. The former, because it is based upon a single number index in current usage, is a particularly useful tool for architects. Apart from the doubts raised by the field trials however the following deficiencies must also be noted because they indicate the general lines along which the predictive method of Chapter VI has been developed. Young's method does not:-

a Give specific guidance as to the relationship between laboratory and field data, particularly with regard to flanking transmission.

b Evaluate the relationship between voice level and ambient level.

c Take into account shielding effects due to building configurations and extraneous obstacles.

d Describe how dBA levels may be measured or estimated.

e Deal with special conditions, e.g. partitions containing doors.

In the early stages an attempt was made to work with predictive methods in parallel, based upon a single number index and 1/3 octave analysis. Subsequently the second method was discarded as it did not appear to promise a significant increase in the accuracy of prediction. Moreover the task of the designer using the method was increased enormously because of the necessity for obtaining 1/3 octave data as an input. A method of this degree of complexity would seem to call for the use of computor facilities with all relevant 1/3 octave data stored in the computor memory bank, or alternatively on punched cards or paper tape. As a research tool this may be desirable but it would not, at the present stage of office practice, meet the needs of the architect.

Once a decision was taken to concentrate upon a single number index system the question arose as to the best index to use. Previous work had shown that measurements based upon the dBA unit correlated well with equivalent indices such as speech interference level, loudness level and noise rating curves.[24,25,26] The dBA was adopted by the Wilson Committee in 1963[27] and has been consistently used by the National Physical Laboratory and the Building Research Establishment during the last decade for noise climate analysis. The overriding consideration was therefore, that most of the data for background noise accumulated over recent years has been determined by analysing the A-weighted level, at intervals over a given period of time and carrying out a cumulative count to ascertain the L_{10}, L_{50} and L_{90} levels.

For the present the dBA L_{10} level has generally been adopted in this country to express the limit for traffic noise in relation to buildings. Ultimately this may be replaced by an alternative single number system such as the Traffic Noise[28] or Noise Pollution Index[29]. In this event there should be no difficulty in applying any such system to the predictive method of Chapter VI.

II CRITERIA FOR AMBIENT NOISE AND SOUND INSULATION.

2.1 General.

The empirical nature of the speech privacy criterion of BS CP3 Ch III is self-evident. It can also be shown that sound insulation grading curves in general use in Europe and the U.S.A. are similarly based.[30,31,32] The procedure which is used to arrive at these national standards involves large scale surveys to determine the reactions of the occupants of buildings. The results of these surveys are then matched with measurements of the various constructions employed. The grading curves which result from this method of formulating standards inevitably resemble the measured sound insulation curves for the construction in most general use.

When a radically new system of construction is involved, in a context alien to that for which it was originally designed, the previously described method of establishing a criterion may not be the most suitable; particularly when the system of construction has been evolved or selected to produce the maximum number of buildings within a limited time span i.e., within the constraints of a relatively short term but large scale building programme. It has already been explained in the preface that these were the circumstances which surrounded the present study.

A method was therefore required to rapidly establish a specific insulation criterion curve for consulting rooms in various locations and to assess the performance of the metal faced partition against this criterion. Medical ethics precluded measurements of actual consultations, to determine factors such as speech levels, speech rates and noise generated within the consulting room.

The use of electronic simulation techniques had been shown to be valid by the work of Cavanaugh et al and also by earlier research.[33] It was decided therefore to adopt this approach to establish the criterion curve which would relate insulation requirements to ambient noise levels, both for consulting rooms and waiting areas.

One sub-group (subject nos 1, 2, 3, 7, 8, 10, 12 and 14) used in the laboratory experiments was drawn from the various central government departments involved in decision making in relation to health centres and outpatient departments. The other sub-group (subject nos 4, 5, 6, 9, 11, 13 and 15), which comprised general practitioners and laymen, represented the potential building occupants.

2.2 Recommended maximum levels for ambient noise.

Preliminary discussions with S.H.H.D. advisors, and administrative officers of the health centres visited, suggested that the background noise limits for consulting rooms should be similar to those for small executive offices of a more general character. Special functions, such as the use of the stethoscope and preliminary hearing tests (not exacting audiometric tests), did not call for specific criteria, providing that the general noise level was such that the telephone could be used with a reasonable degree of intelligibility. The suggested L_{50} limit for ambient noise, based upon the speech interference concept, is 42 dBA; such a level would not interfere unduly with either telephone or stethoscope, or with quiet conversations between doctor and patient. Higher levels, up to 50 dBA, may be tolerated for the limited period that the room is in use by a doctor during a consulting session. Such levels are undesirable for longer periods of executive work or concentrated study and may at times interfere with the use of both telephone and stethoscope. (Background noise may of course be expressed in alternative criteria such as Noise Criterion, Noise Rating, Preferred Noise Criterion or Background Noise Level curves, in addition to such units as Traffic Noise Index or Noise Pollution Level.)

The proposed 42 dBA ambient noise criterion applies to road traffic noise and relatively steady-state noise components which blend to form the background noise climate. It does not apply to intermittent sources such as jet aircraft with noise spectra which need special consideration. Ventilation fans and air conditioning equipment may also require special attention if they generate relatively high levels at discrete frequencies. In these latter cases spectrum analysis is essential, plotted in relation to noise rating curves.

Previous research had indicated that the lower limit of background noise in consulting rooms was unlikely to be less than 30 dBA (L_{50}). At the other extreme the probable limit in waiting areas is 50 dBA (see Chapter III). The range of ambient noise for the laboratory simulations was therefore taken as 30 - 50 dBA. This range compares with that of approximately NC 25 - 35 (34 - 42 dBA) used in previous experiments by Cavanaugh et al.[34]

2.3 Speech variables.

In order to predict the degree of privacy between rooms the following factors must be taken into account:-

a) Speech levels generated in the adjacent room and the relative importance of the various speech components.

b) Noise reduction characteristics of the partition, including for such effects as flanking transmission.

c) Masking effect of the ambient noise in the receiving room.

d) Aural acuity and level of awareness of the listener.

The average conversational speech level depends not only upon the vocal power and inflection of the speaker but also the volume and sound absorption characteristics of the room. It is also generally accepted that it depends upon the ambient noise, if the latter is at a fairly high level.[35] One question, to be answered by the laboratory experiments, was whether the voice level is influenced by the relatively low ambient levels required for the consulting room, even if such levels do not directly affect speech articulation between doctor and patient.

Various predictive methods, based upon speech articulation theory, assume that the normal voice level is approximately 60 dBA in the source room and is independent of ambient noise; such a level may not necessarily be the norm for consulting rooms. The same methods also assume that the shape of the speech envelope is unaffected by the variations of total room absorption in relation to frequency. It is also suggested that adjustments may be made to the 60 dBA reference speech level for a) raised voice (65 - 66 dBA) and b) very loud voice (70 - 72 dBA). At least one source indicates that the female reference voice may be 5 dBA lower than the male equivalent.[36]

The nomograms of Figs 2.1a and 2.1b show the variations which may occur in both average level and dynamic range (with respect to frequency) in a small room containing approximately $10m^2$/sabins of total absorption. Fig 2.1a is the predictive nomogram of Cavanaugh et al and 2.1b is a similar one proposed by Bains.[37,38]

Other speech variables follow from the emotional state of the speaker. Change in speech rate and spectral characteristics have been examined by Wilson and Stevens.[39] They quote mean syllable articulation rates of 1.91, 3.80, 4.15 and 4.31 for the corresponding emotional states of sorrow, fear, anger and neutral. Assuming a constant ratio of 1.8 syllables per word the equivalent word articulation rates are 64, 128, 140 and 145 words/minute. All of these statistics are for male voice and do not necessarily apply to female speakers. The speech rate quoted by Cavanaugh et al for their experiments was standardized at 100 words/minute.

One critical aspect of the articulation theory is that the syllable articulation rate is determined by listening tests, using random syllables and the degree of word or sentence comprehension follows from the relationship postulated in Fig 2.2. Serious discrepancies can occur during this transformation due to the critical shape of the curve, particularly in the 0 - 30% syllable articulation range.[40] A speech privacy criterion must inevitably fall within this critical region.[41]

2.4 Form of laboratory experiments.

The form of the laboratory experiment was determined by the various factors described in previous paragraphs.[42] The type of subject used was unable to spend more than about two hours at a time in the

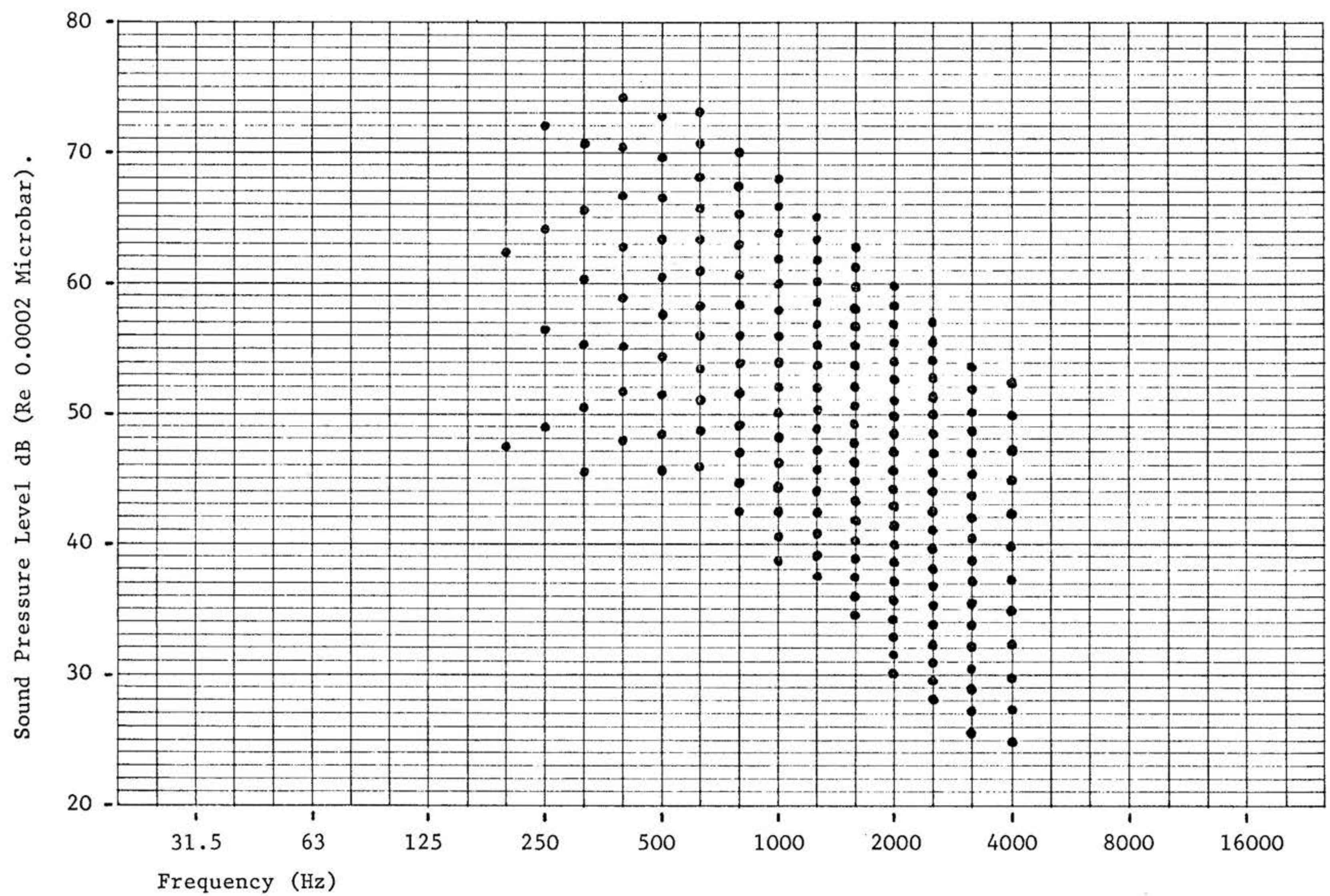


FIG 2.1a PREDICTION NOMOGRAM - LEVEL AND DYNAMIC RANGE OF SPEECH INRELATION TO FREQUENCY (AFTER CAVANAUGH ET AL).

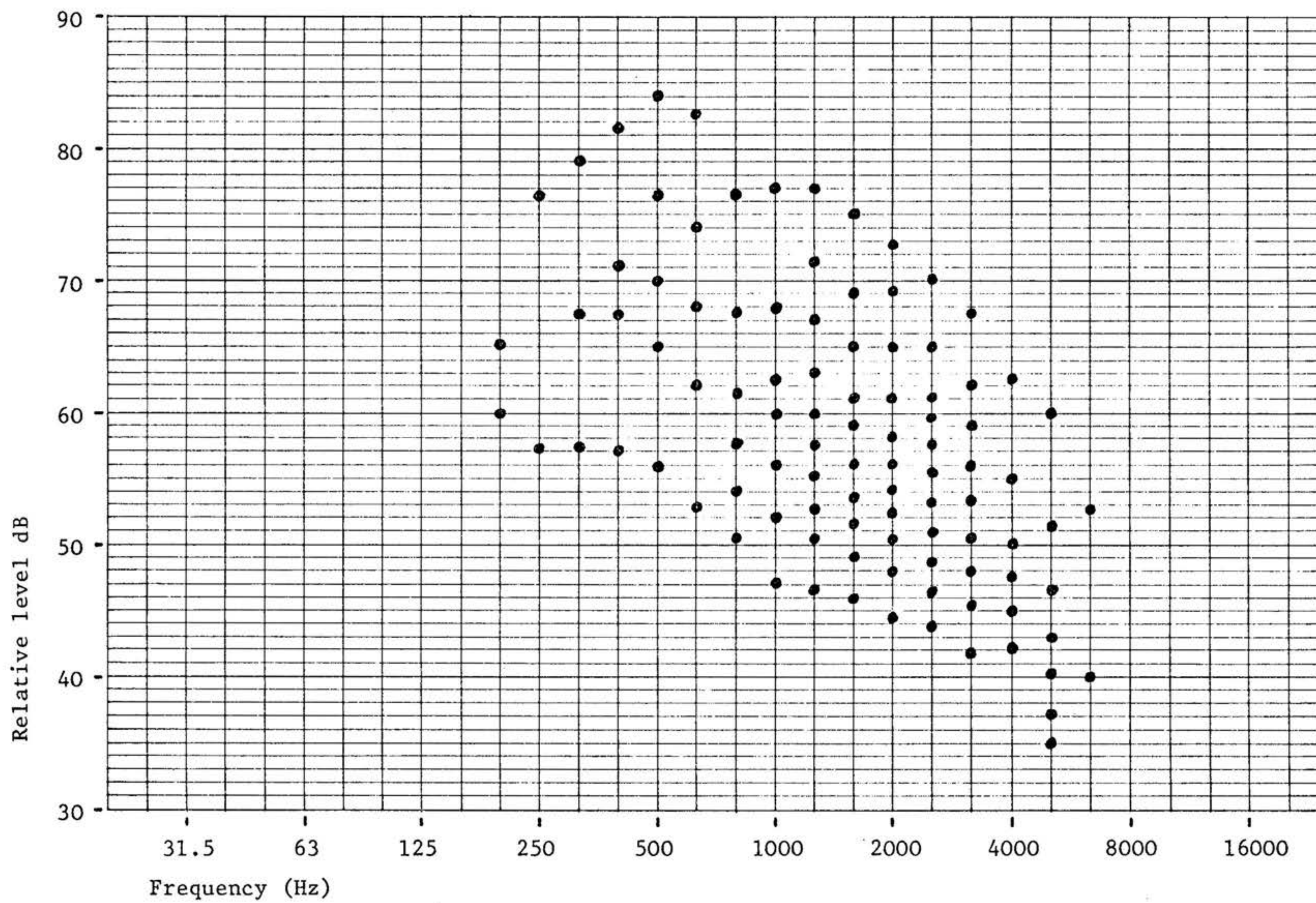


FIG 2.1b PREDICTION NOMOGRAM - LEVEL AND DYNAMIC RANGE OF SPEECH IN RELATION TO FREQUENCY (AFTER BAINS).

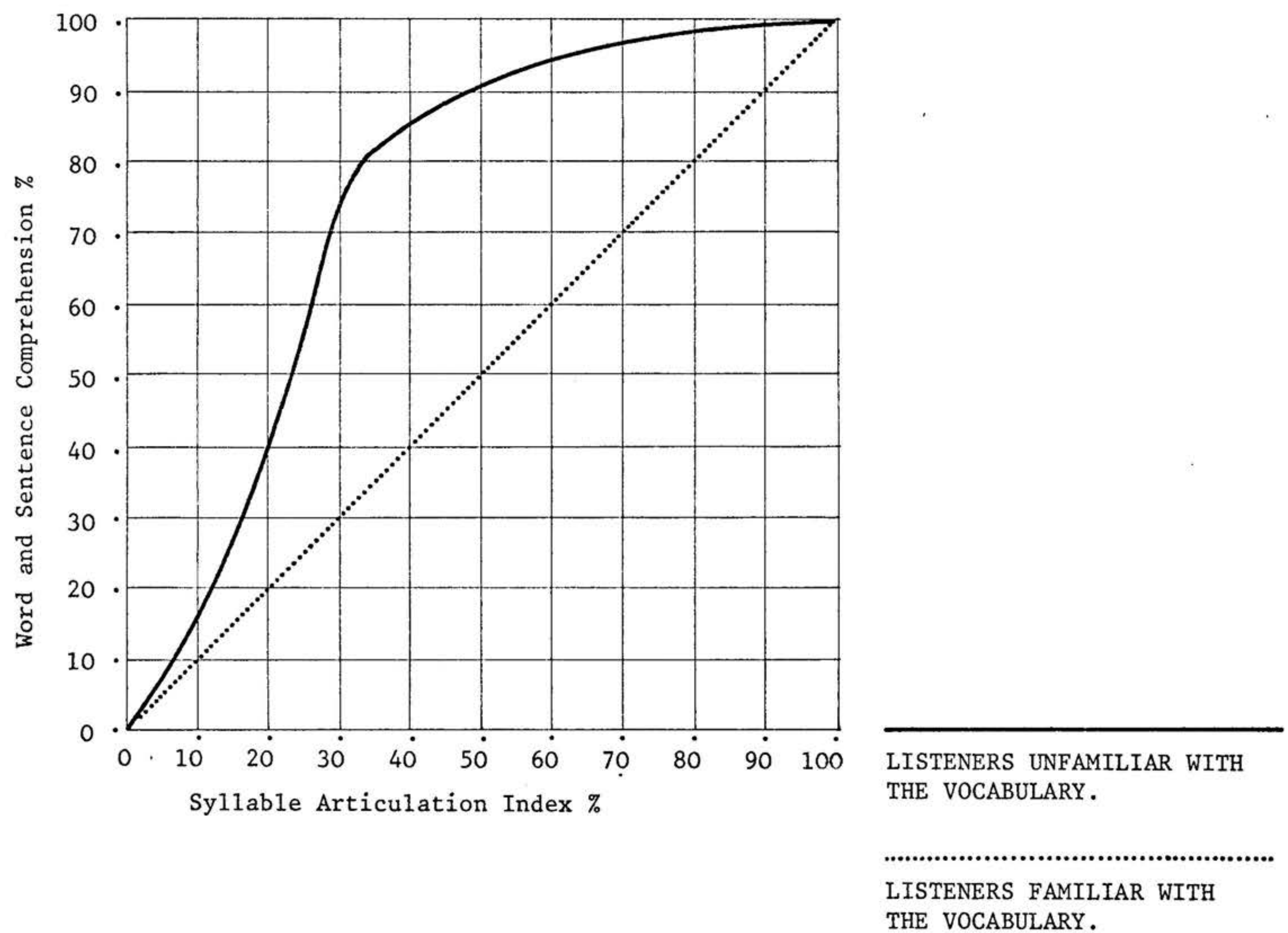


FIG 2.2 SPEECH ARTICULATION THEORY - APPROXIMATE RELATIONSHIP BETWEEN SYLLABLE ARTICULATION AND WORD OR SENTENCE COMPREHENSION.

laboratory. This meant that the duration of each experimental run was critical, suggesting a multivariate structure for the experimental sequence.

Speech rate, sex of speaker, age and sex of subject and ambient noise were treated as grouped factors; voice level and degree of insulation required became the dependent variables, to be determined by the subject using the attenuator on the desk at which he was seated. Speech rate, speech level and sex of speaker were randomized.

The level of ambient noise was not randomized; to do so would have required rapid adaptive shifts which could be as great as 20 dB, from the subject. Instead, the change of level between successive passages was limited to 2 dB and the general ambient level moved in a wave-like formation over the 20 dB range.

Table 2.1 lists the variables and grouped factors, as incorporated on the test tape.

The general layout of the room in which the subjects were seated and the associated control room is shown in Fig 2.3a. This figure also incorporates a block diagram of the instrumentation. The positions of speech and noise sources in relation to the subject were apposite to those for a typical consulting room. The test room was heavily damped, as is the fully furnished and carpeted consulting room (see Chapter V, Section 5.4), the reverberation times being shown relative to frequency in Fig 2.3b.

Speech passages corresponding to the data of table 2.1 were prerecorded on channel 1 of the tape and the ambient noise on channel 2. The ambient noise spectrum was shaped to correspond to the slope of Noise Rating Curve 25 (Fig 2.4). The amplifier and tape

1 SPEECH PASSAGE NUMBER	2 REFERENCE SPEECH LEVEL (dBA).* (RANDOM SEQUENCE)	3	4 a. GROUPED INDEPENDENT VARIABLES LEADING TO STANDARD ERROR. (Random Sequences.)** SPEECH RATE (Words/Min.)	b. SEX OF SPEAKER.	c. NUMBER OF WORDS IN PASSAGE.	d. DURATION OF PASSAGE (Seconds).	5 MAJOR INDEPENDENT VARIABLE - ARTIFICIALLY INDUCED AMBIENT NOISE LEVEL (dBA).
1	65.4	DEPENDENT VARIABLE OBTAINED FOR EACH EXPERIMENT BY SUBTRACTING ATTENUATOR SETTINGS FROM COLUMN 2.	223	F	327	88	40.6
2	64.9		132	M	307	140	42.6
3	68.2		118	M	256	130	44.6
4	69.1		125	M	312	150	46.6
5	69.5		221	F	291	79	48.5
6	68.0		134	M	216	97	50.1
7	69.0		183	F	256	84	48.3
8	66.1		119	M	300	151	46.4
9	67.0		212	F	286	81	44.6
10	66.5		176	F	282	96	42.9
11	65.1		159	M	394	149	41.1
12	67.3		138	M	253	110	39.3
13	68.2		201	F	480	143	37.6
14	68.8		117	M	224	115	35.7
15	67.9		212	F	325	92	34.3
16	69.1		167	F	320	115	33.2
17	69.3		165	F	217	79	34.4
18	67.7		137	M	220	96	35.5
19	69.3		167	F	240	86	37.5
20	67.5		141	M	216	92	39.5

* Figures based upon average of measurements in the listener position.

** Figures based upon an analysis of the test tape.

TABLE 2.1 VARIABLES FOR LABORATORY EXPERIMENTS.

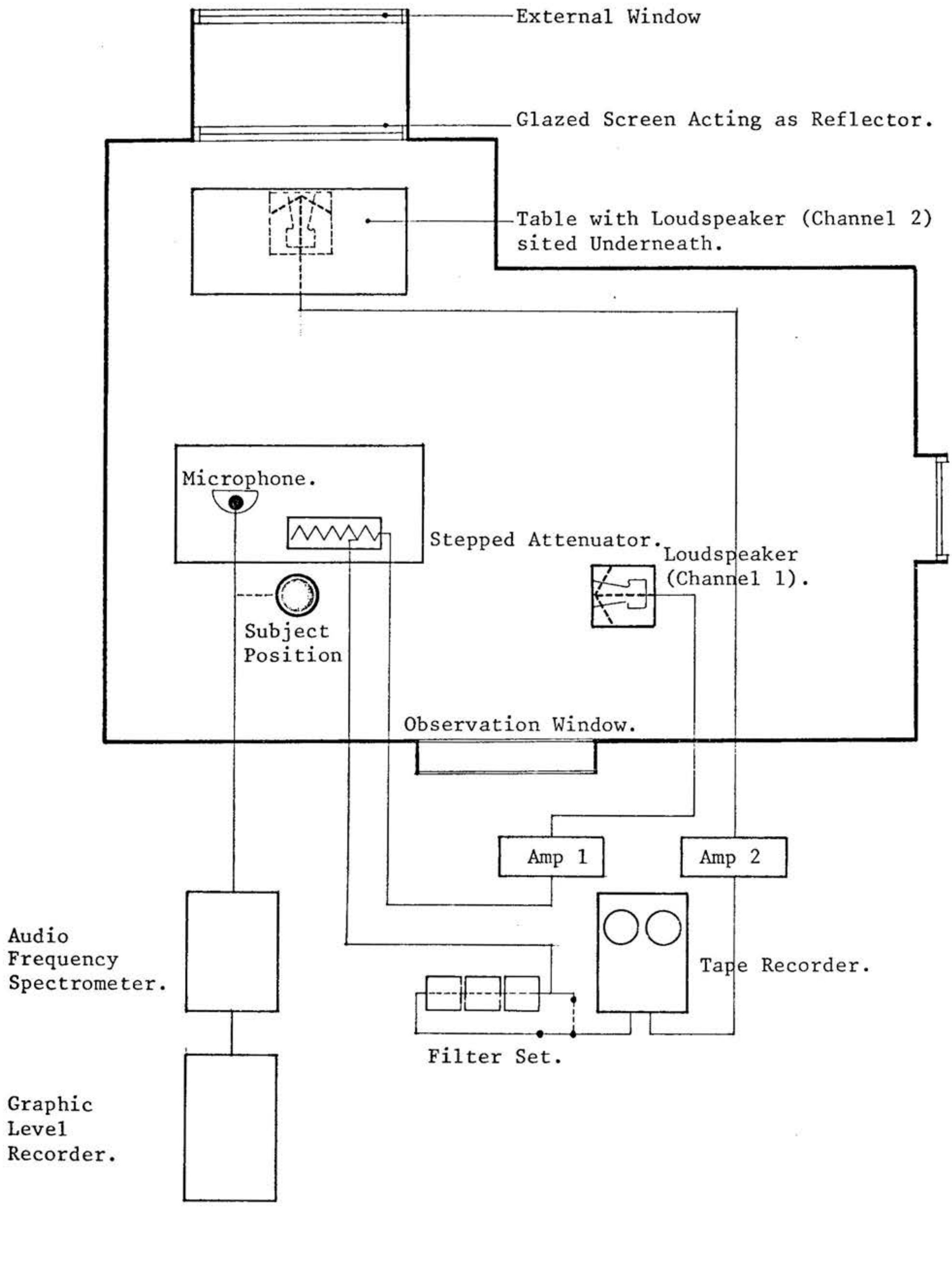


FIG 2.3a LAYOUT OF ROOM USED FOR LABORATORY EXPERIMENTS AND DIAGRAM OF INSTRUMENTATION.

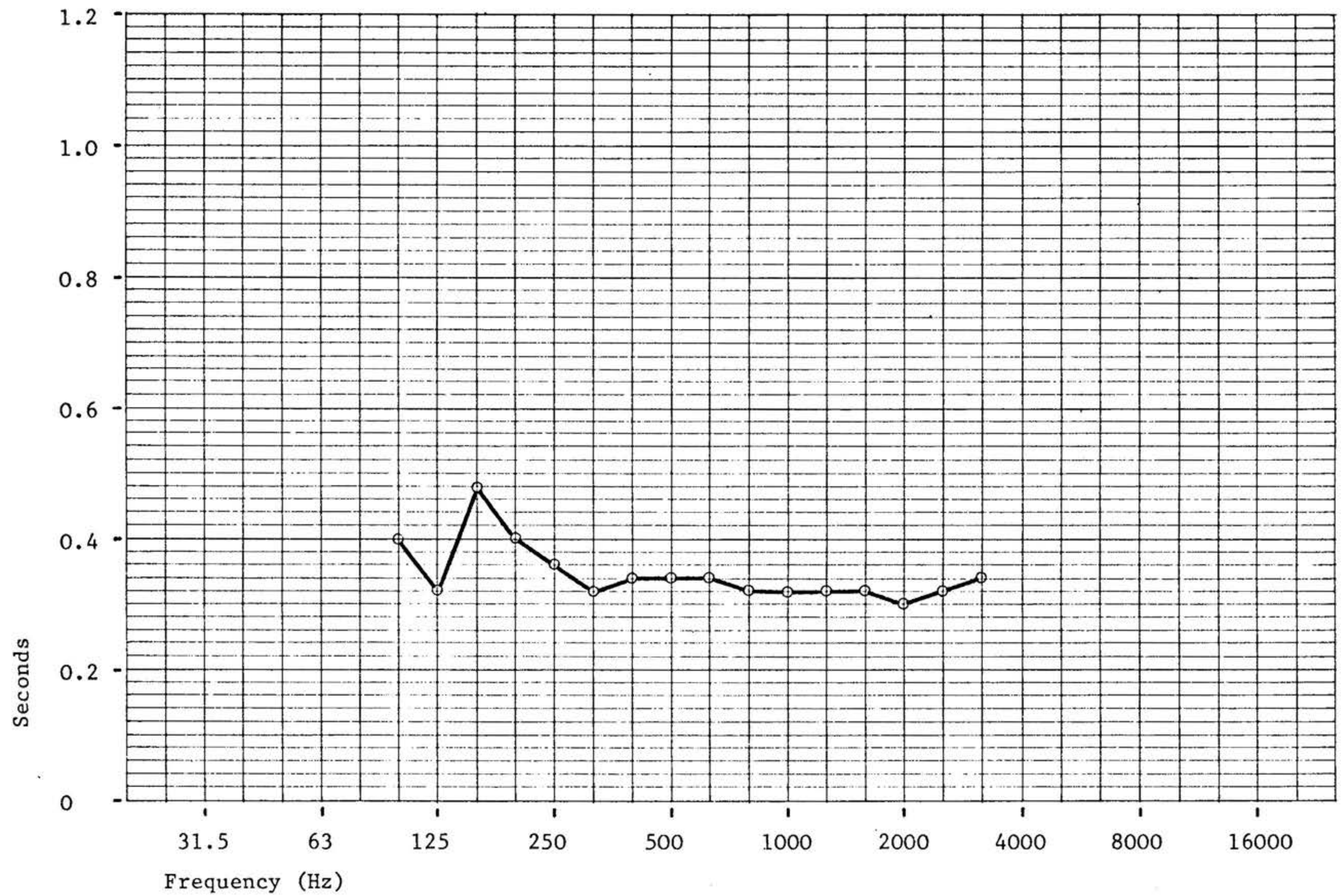


FIG 2.3b REVERBERATION TIME CHARACTERISTICS OF ROOM USED FOR LABORATORY EXPERIMENTS.

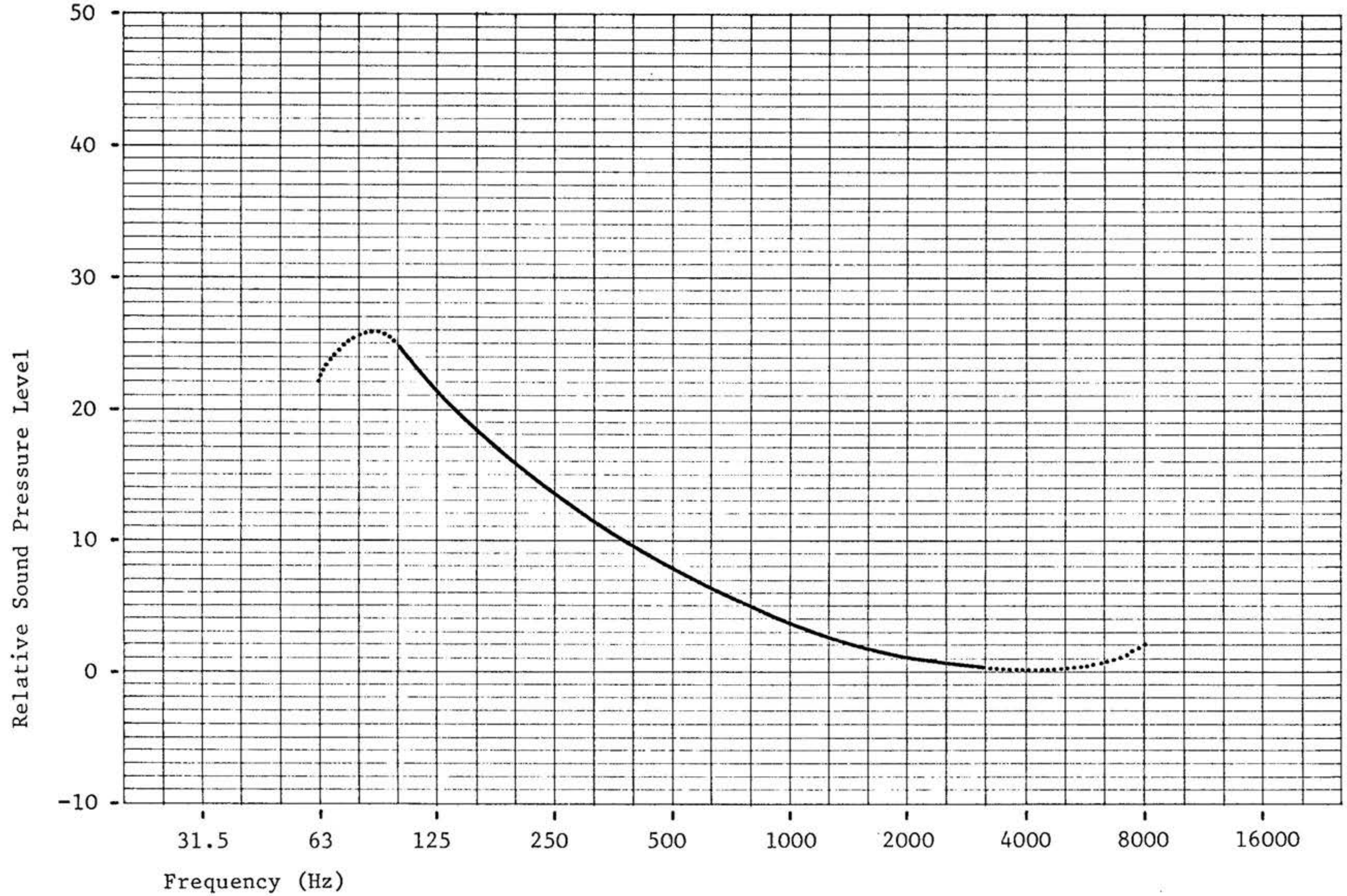


FIG 2.4 AMBIENT NOISE SPECTRUM USED IN EXPERIMENTS.

recorder gain controls were set to predetermined playback levels. All other experimental variables were outwith the control of the operator thus minimizing errors due to changes in control settings.

The subject was presented with a written set of instructions as in table 2.2. These required him, in test sequence 1a, to establish the 'normal' voice level and in sequences 1b, 1c and 1d, to arrive at sets of decisions regarding the sound insulation which he considered just adequate between consulting rooms. The total group of fifteen subjects completed all test sequences.

The spectrum shaping filter network was switched out for experiments 1a and 1b. The attenuating spectrum was therefore constant with frequency. After a period of several weeks the subjects were asked to return and repeat two further experimental runs for which the instructions to the subject were identical to those of 1b. For experiment 2a however, the shaping network was switched in, without informing the subject.

The spectrum slope of the filter network had been previously calibrated to correspond as closely as possible to the attenuation slope characteristics of the CLASP Mk 4B partition. The gain of the filter network was also calibrated so that the mean of the spectrum, measured in 1/3 octave bands, was constant irrespective of whether the filter network was switched in or out.

If for any reason the subject felt unable to arrive at a firm decision during any one speech passage he was able, by pressing a repeat switch, to request the operator to replay any particular passage. In actual fact very few repeats were called for. The background noise level was verified at the beginning and end of

EXPERIMENT NO 1a.

Upon pressing the "Proceed" switch you will hear an announcement giving a passage number, followed by a short recorded passage.

Use the control box on the desk to adjust the voice level until it seems at an appropriate level for the consulting room.

Immediately after making your final setting of the controls, make a note of the setting numbers in the experimental log and then reset the controls to read 10 dB.

If you are unable to decide on the appropriate level and make the necessary adjustments before the passage ends, press the "Repeat" switch. After a short pause the passage will be repeated.

EXPERIMENT NOS 2a, b & c.

Upon pressing the "Proceed" switch you will hear the same sequence of recorded passages as before.

Imagine that the speaker is in an adjacent consulting room. The control box may now be used to establish various degrees of sound insulation between the speaker and yourself. Adjust the controls to provide a just adequate degree of insulation.

After arriving at a satisfactory setting, note the numbers in the log and reset the controls to 30 dB.

If necessary use the same repeat procedure as in Experiment No 1.

TABLE 2.2 INSTRUCTIONS TO SUBJECTS, PRIOR TO LABORATORY EXPERIMENTS.

each experimental session and was typically 20 - 22 dBA. If for some reason the general ambient level rose above 22 dBA the test sequence was suspended. This happened on two occasions due to high external wind noise. Occasionally extraneous noise from the approach stairway encroached into the 8 - 10 dB margin between the lowest simulated ambient noise level of 30 dBA, and the actual background noise levels already quoted. When this occurred the subject waited until the intruding noise ceased before making a judgement, or if necessary evoked the 'repeat passage' procedure.

Every experimental run was monitored using a precision sound level meter with A-weighting network coupled to a graphic level recorder. The microphone was placed on a stand in close proximity to the subject and at head level. The resulting traces showed both the actual ambient level and the dynamic speech range, the latter as adjusted by the subject.[44]

2.5 Results of experiments.

The results of all experiments are summarized in Figs 2.5 - 2.8. In these graphs the ambient noise level is treated as the major independent variable.

The dependent variable for experiment 1a is the normal voice level, based upon the subjects' experience. The graphs of Fig 2.5 produced by linear regression analysis, show that under these experimental conditions the voice level tends to be dependent upon the ambient noise. The rate of regression varies for each sub-group, as shown by the graphs.

In experiment 1b (Fig 2.6) the dependent variable is insulation required, when the sound insulation is constant with frequency. As

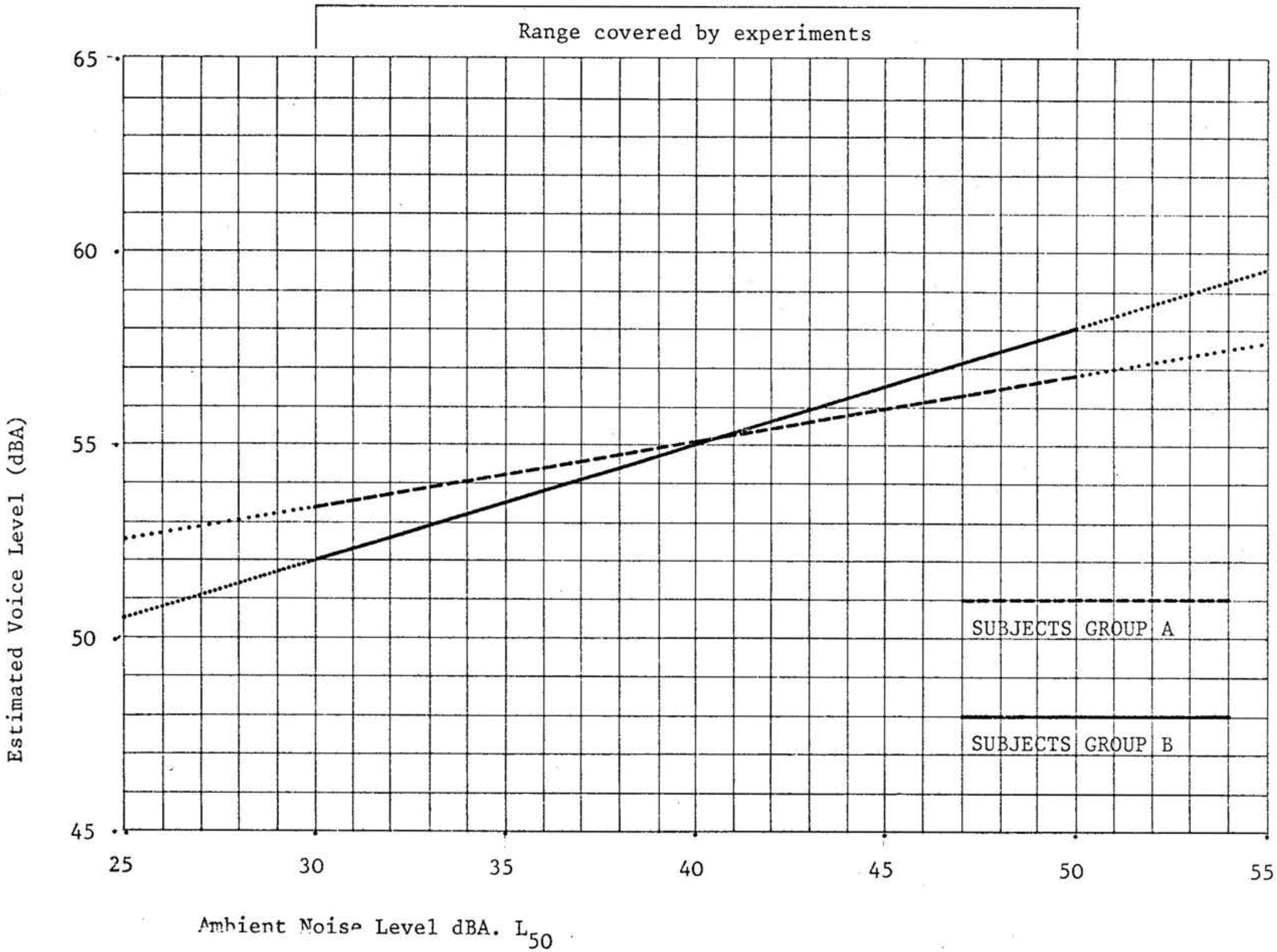


FIG 2.5 RELATIONSHIP BETWEEN NORMAL VOICE LEVEL AND AMBIENT LEVEL IN CONSULTING ROOMS

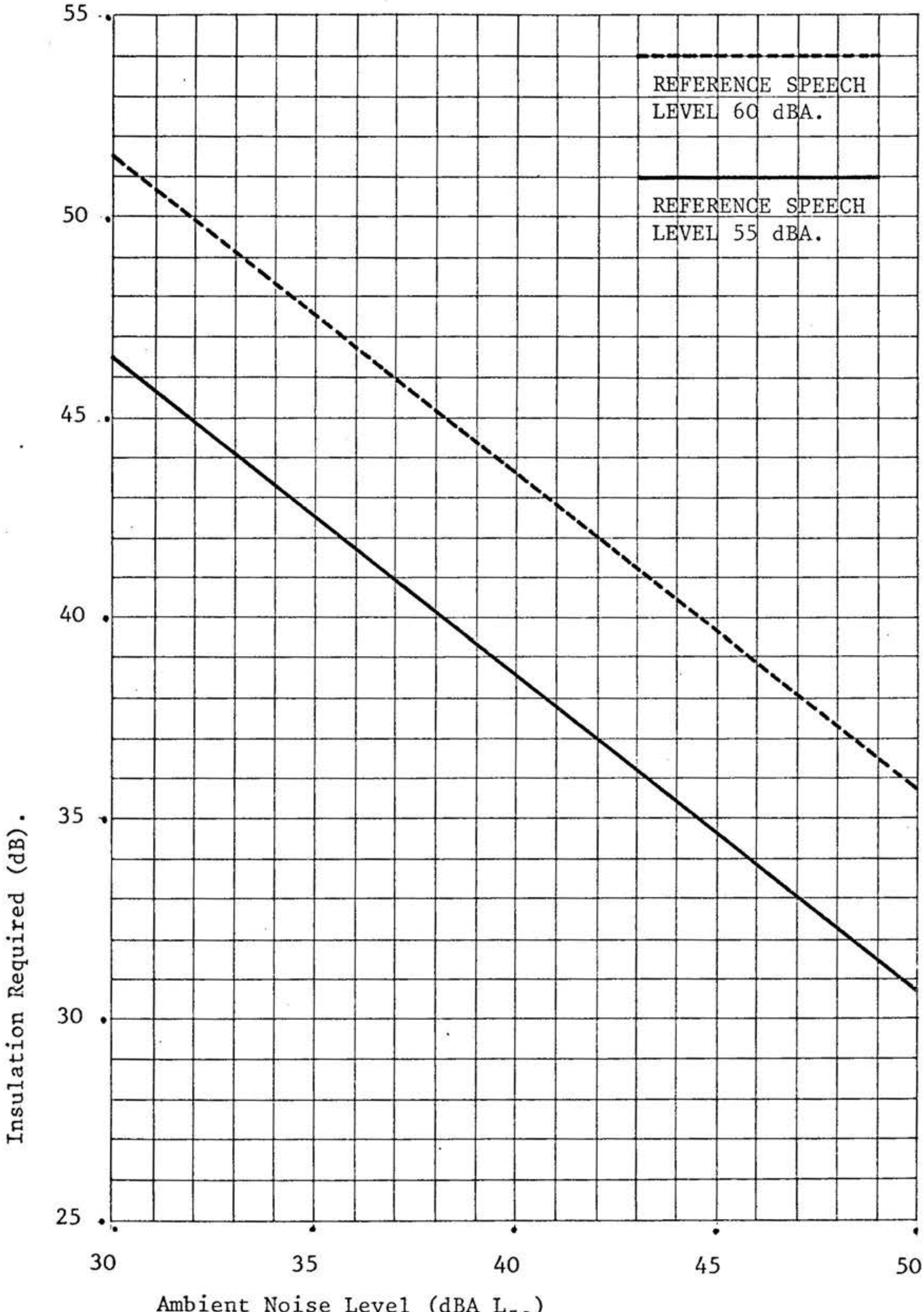


FIG 2.6 INSULATION REQUIRED FOR SPEECH PRIVACY WHEN SPEECH LEVEL IS CONSTANT AND ATTENUATION IS CONSTANT WITH FREQUENCY.

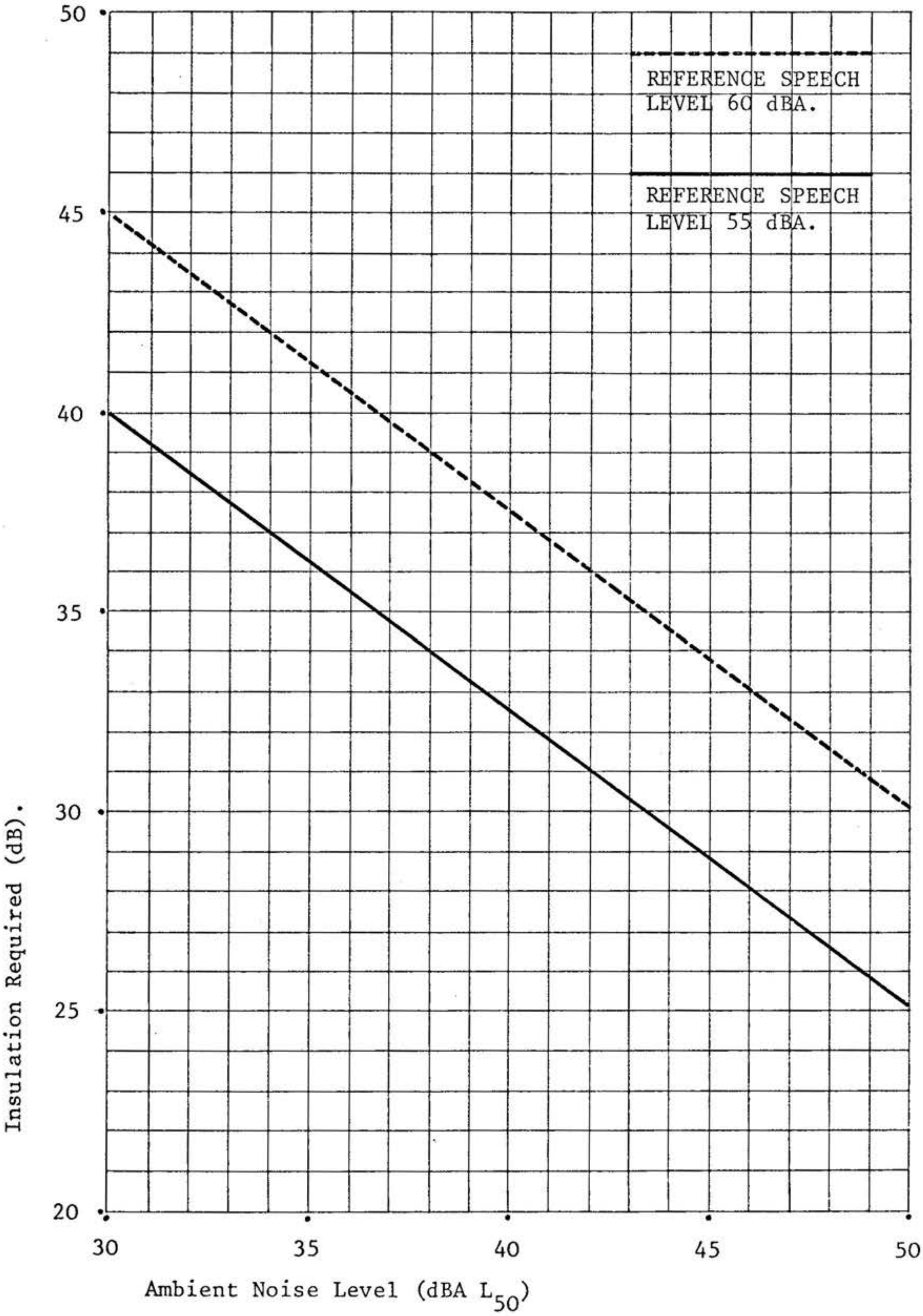


FIG 2.7 INSULATION REQUIRED FOR SPEECH PRIVACY WHEN SPEECH LEVEL IS CONSTANT AND THE ATTENUATION SPECTRUM IS SIMILAR TO THAT OF THE CLASP 4B PARTITION.

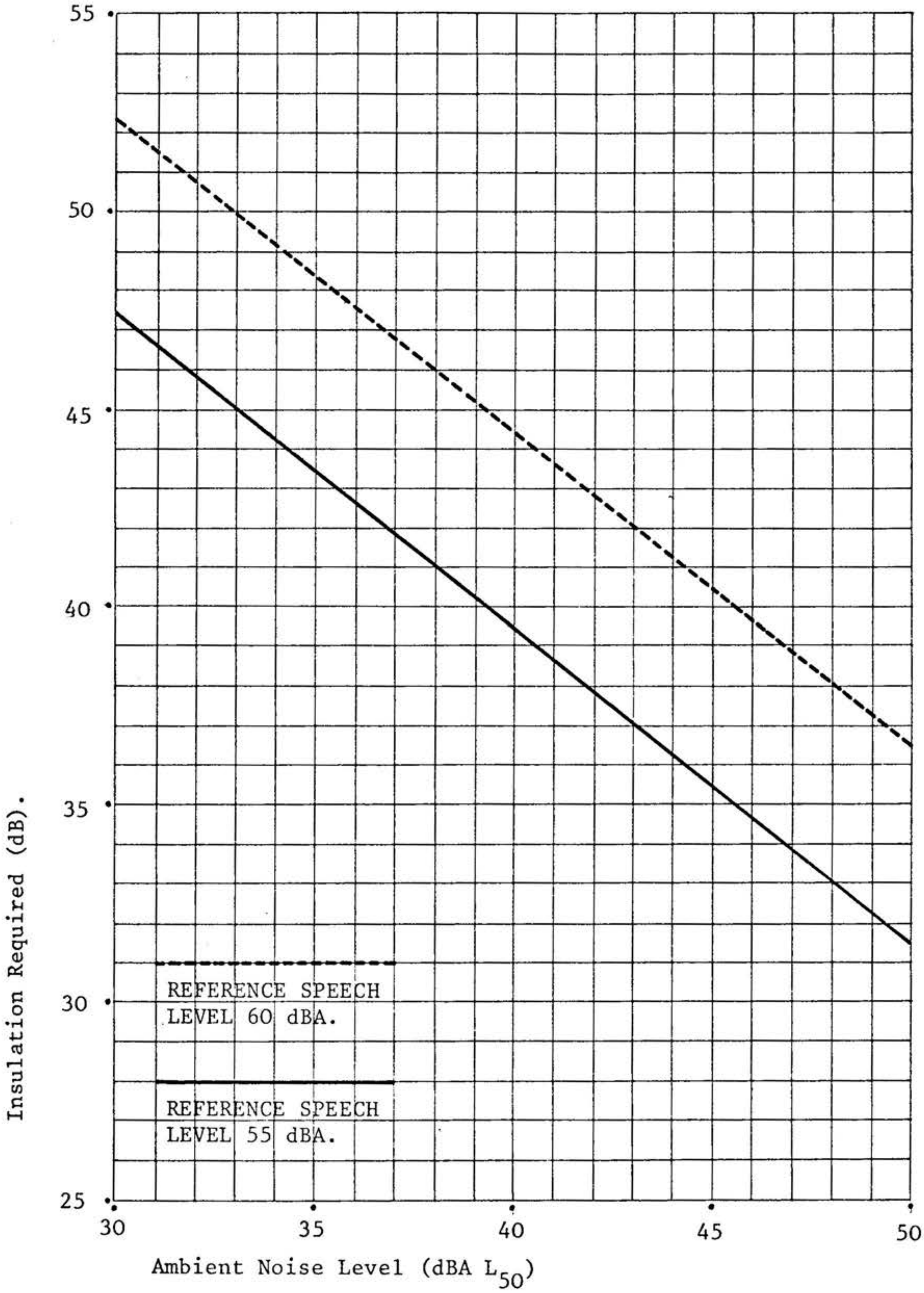


FIG 2.8 REGRESSION LINES FOR EXPERIMENT 2b.

anticipated the insulation required is only approximately inversely proportional to ambient noise, 38.6 dB of insulation being required at 40 dBA ambient level and 30.7 dB at 50 dBA. (Speech reference 55dBA)

In experiment 2a (Fig 2.7) the dependent variable is the insulation required when the sound insulation characteristics with respect to frequency are similar to those of the CLASP Mk 4B partition. In this instance the insulation required is still inversely proportional to ambient noise but the absolute insulation requirements are reduced by 6 dB, being 32.6 at 40 dBA and 25.2 at 50 dBA respectively.

In experiment 2b (Fig 2.8) the conclusions are similar to those of experiment 1b, the only significant difference being a shift of insulation requirements of 0.8 dB. This may be due to experimental errors or learning effect, the same twenty speech passages being used throughout all experiments. The most significant result from this experiment is obtained however, by studying the repeatability of experiments 1b and 2b in terms of the product moment correlation coefficient. If all readings from experiment 1b are correlated with those of 2b the coefficient of stability is 0.87 which is highly significant, suggesting that experimental error was minimal.

2.6 Aural acuity of the listener and associated variables.

The major independent variable used in plotting the graphs of Figs 2.5 - 2.8 was ambient noise level, measured in dBA and with a spectrum conforming to the noise rating 25 curve (see Fig 2.4).

All other factors which may be considered as independent variables were grouped for the regression analysis and therefore contribute to the standard error of estimate. Viewed in this way the standard error may be used as a predictor of the factor of safety relating to speech variables. It will also include to a certain extent for variations in aural acuity on the part of the listener.

It should be borne in mind, in using the graphs, that the test circumstances dictated a high degree of attention on the part of the subject. The latter was virtually cast in the role of eavesdropper; conversely he was also expected to establish the degree of protection which he himself would expect.[45]

2.7 Proposed standards of insulation.

In the previous analysis of experimental results (section 2.5) the dependent variables of speech level and insulation required are treated separately. In each case the ambient noise level is the common independent variable.

In Figs 2.9 - 2.12 the composite regression lines shown (integrating the dependent variables) may be used to predict the actual insulation required, when the ambient noise level is identical on both sides of a partition. The dotted line represents the 'least squares' regression line and the solid line the 95% confidence limit. (The t ratio has been used to adjust for possible bias between sample and population means.)

The solid line graphs of Figs 2.10 and 2.12 are embodied in the predictive method of Chapter VI, converted into intruding speech curves.[46] The complement of four intruding speech curves for experiments 1b and 2a and subjects groups A and B are given in Fig 2.13. As stated previously this family of curves is only strictly applicable when the two consulting rooms have noise climates which are dictated by extraneous noise. In other circumstances, e.g. between consulting rooms and waiting areas, the slope of the curves will alter as the

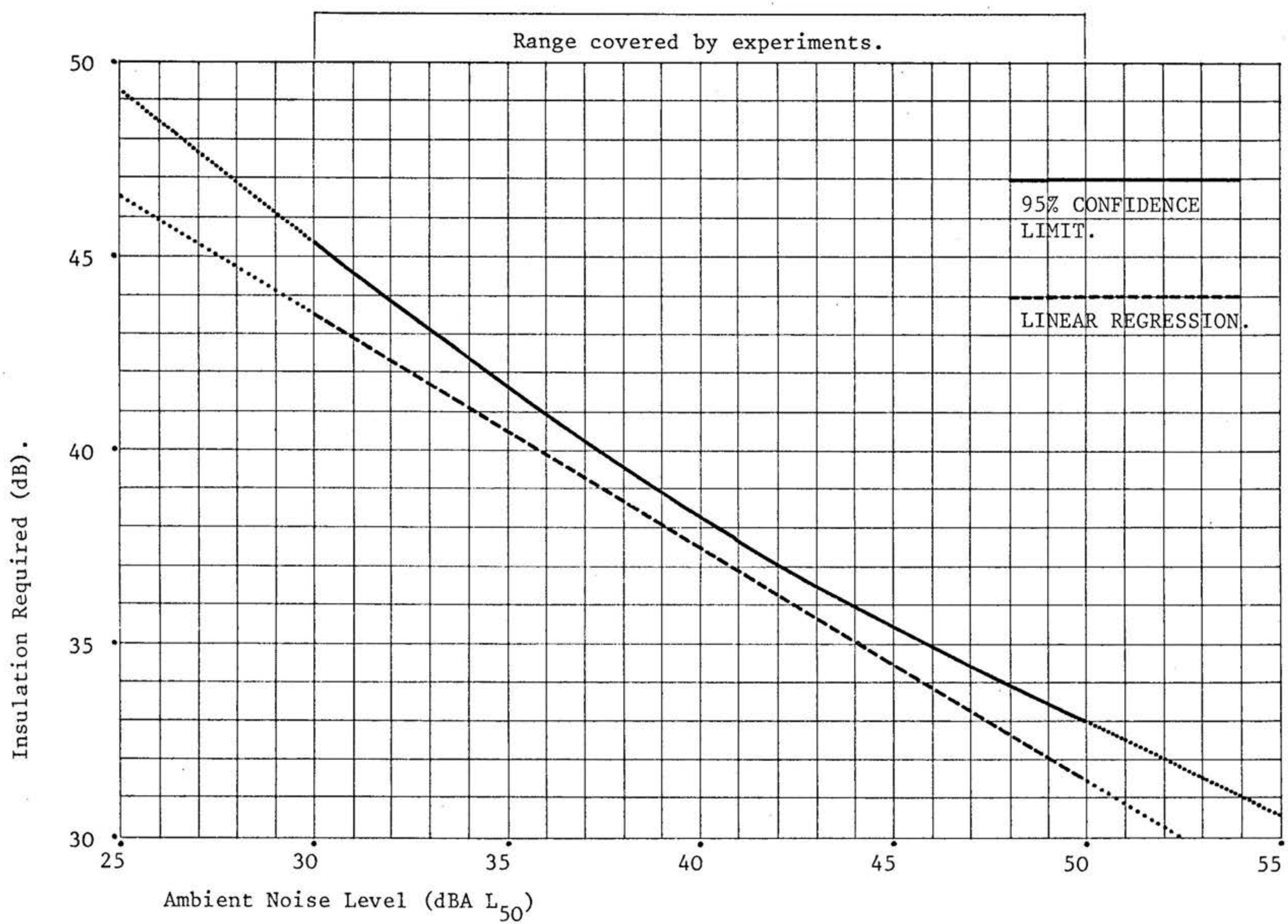


FIG 2.9 INSULATION REQUIRED WHEN SPEECH LEVEL VARIES WITH AMBIENT NOISE LEVEL AND ATTENUATION IS CONSTANT WITH FREQUENCY - SUBJECTS GROUP A.

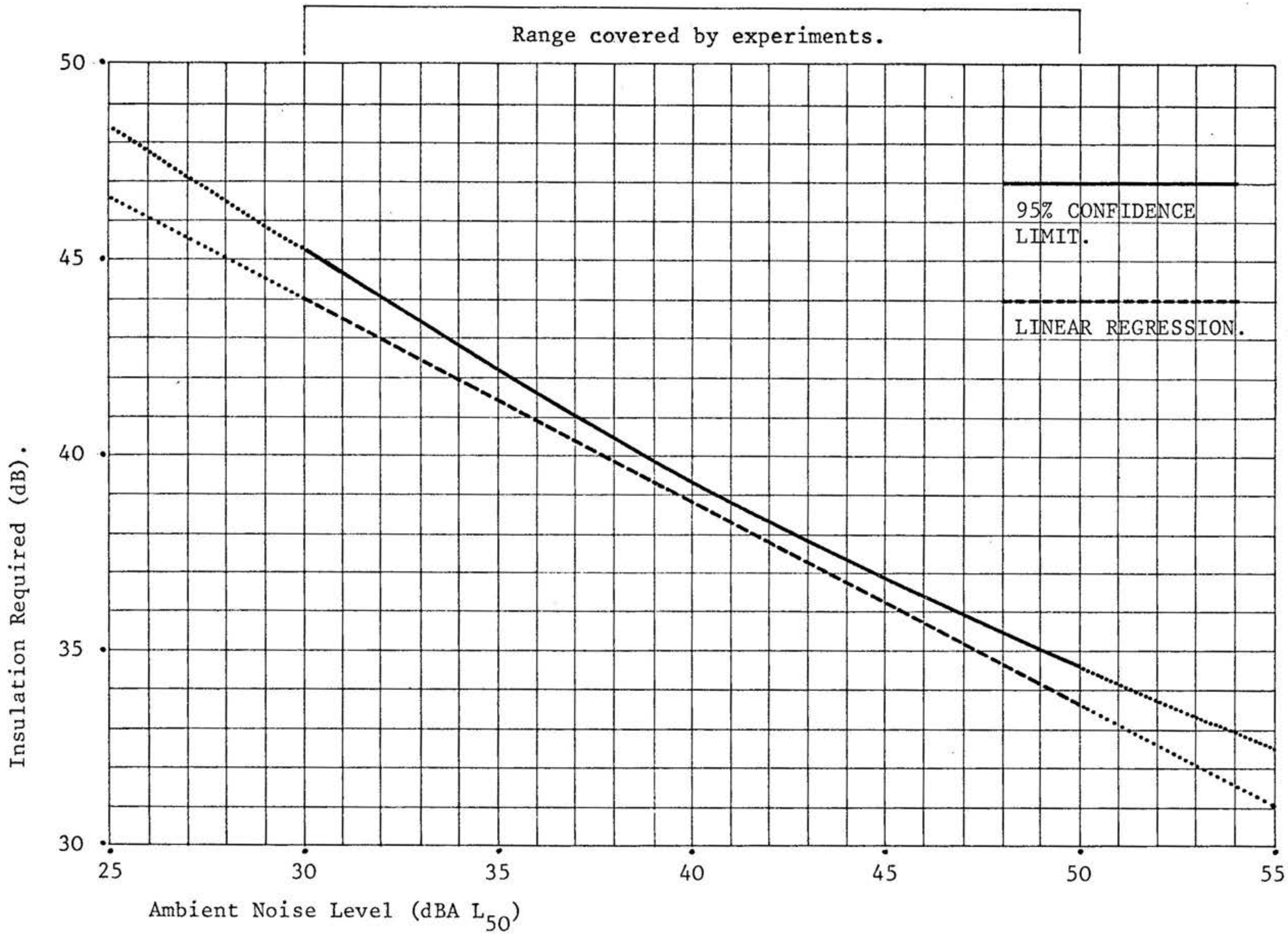


FIG 2.10 INSULATION REQUIRED WHEN SPEECH LEVEL VARIES WITH AMBIENT NOISE LEVEL AND ATTENUATION IS CONSTANT WITH FREQUENCY - SUBJECTS GROUP B.

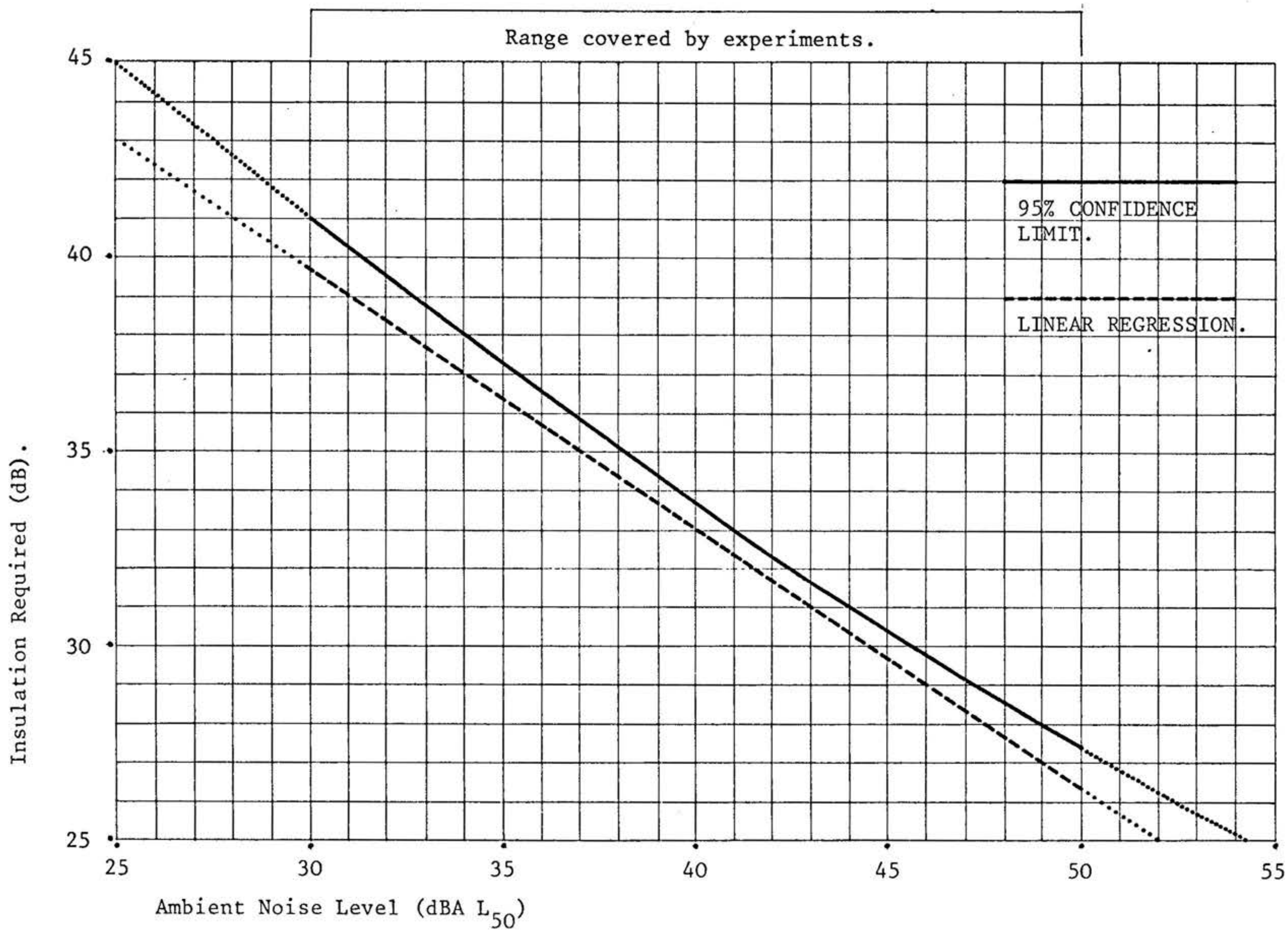


FIG 2.11 INSULATION REQUIRED WHEN SPEECH LEVEL VARIES WITH AMBIENT NOISE LEVEL AND THE ATTENUATION SPECTRUM IS SIMILAR TO THAT OF THE CLASP 4B PARTITION - SUBJECTS GROUP A.

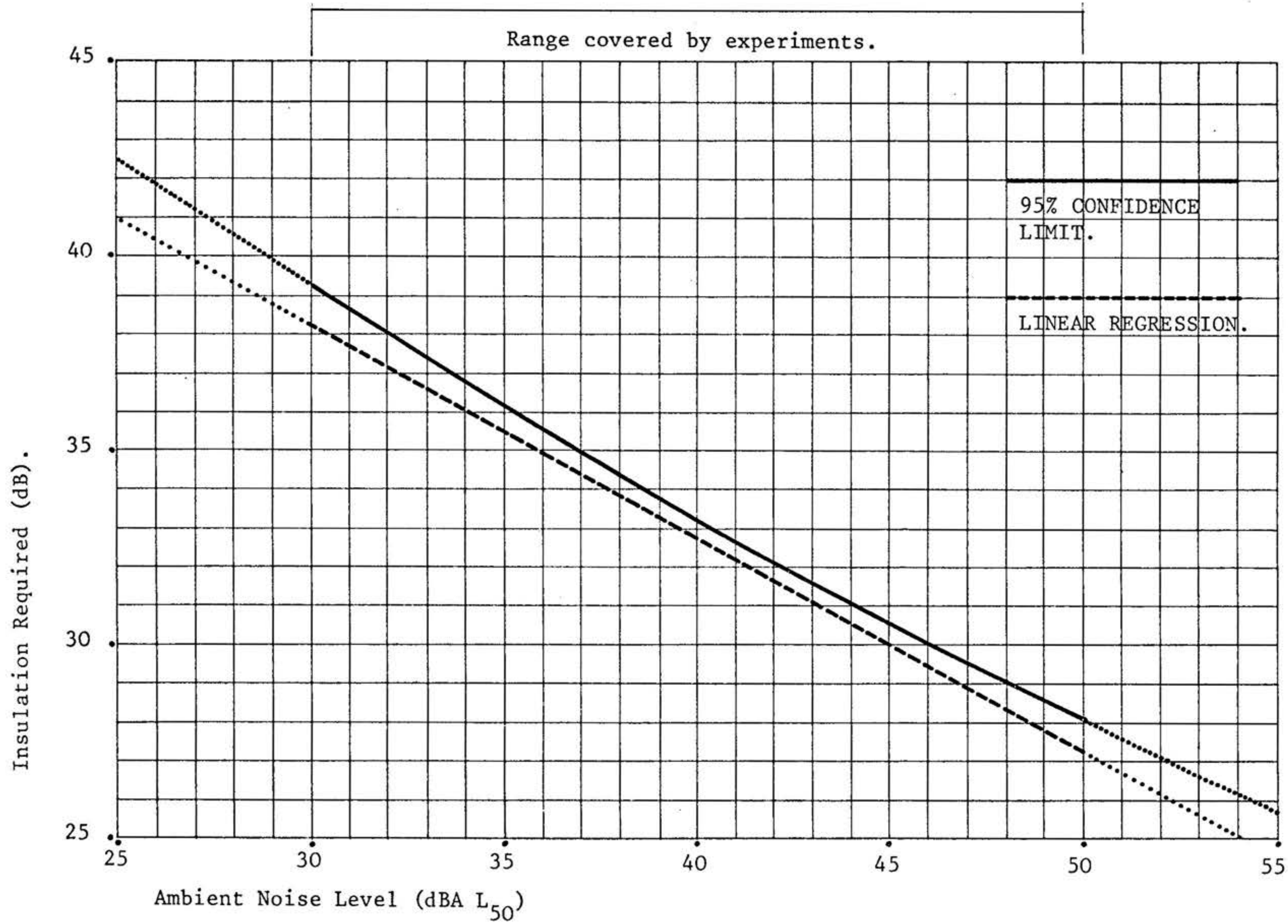


FIG 2.12 INSULATION REQUIRED WHEN SPEECH LEVEL VARIES WITH AMBIENT NOISE LEVEL AND THE ATTENUATION SPECTRUM IS SIMILAR TO THAT OF THE CLASP 4B PARTITION - SUBJECTS GROUP B.

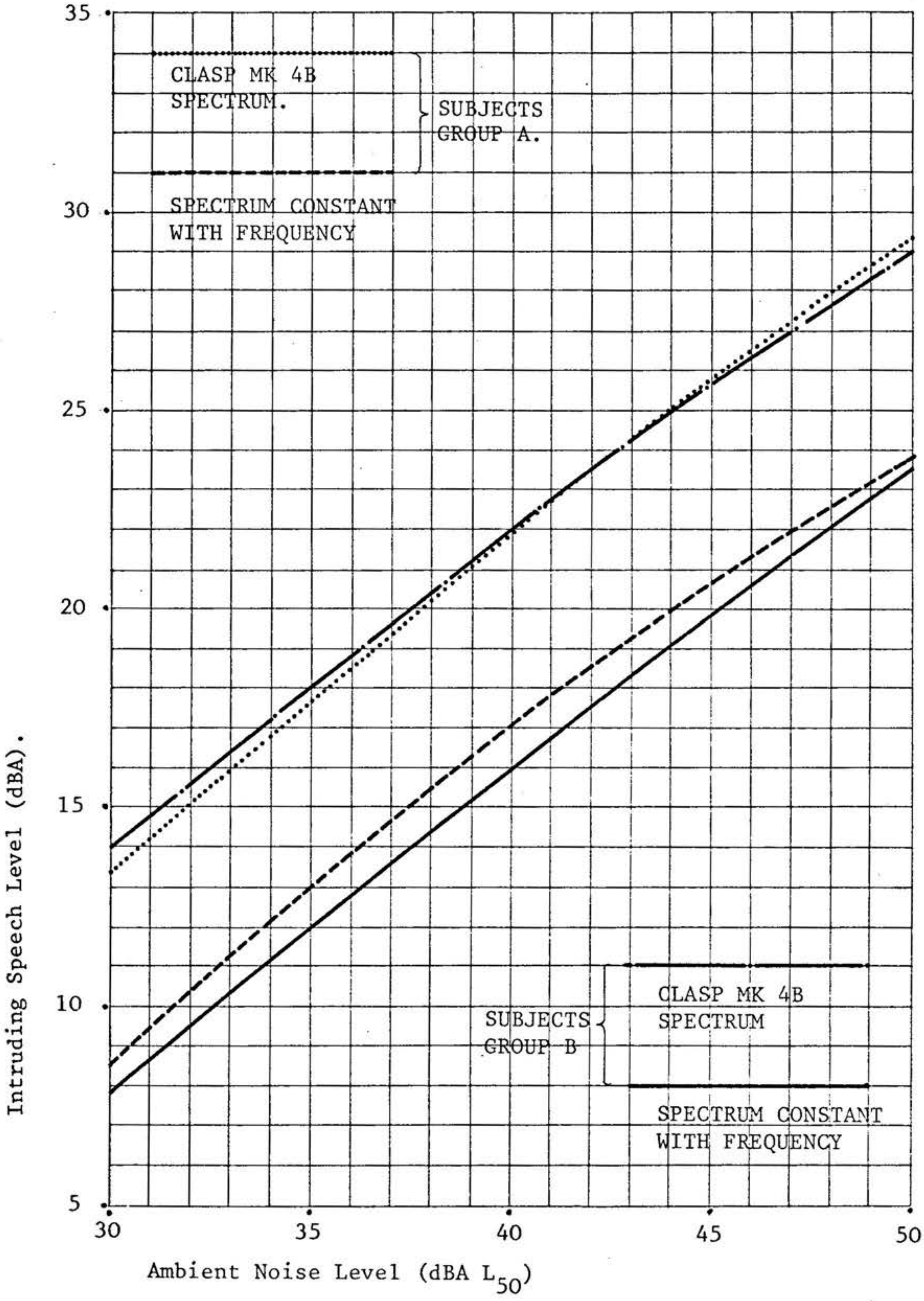


FIG 2.13 PERMISSIBLE INTRUDING SPEECH LEVEL - BASED ON THE 95% CONFIDENCE LIMITS OF FIGS 2.9 - 2.12.

two noise climates differ in level.

In practice, the insulation standards indicated by the laboratory experiments may be considered unduly stringent by some occupants. The probable extent of this variation in opinions may be estimated by reference to Fig. 2.14.

In this diagram a regression line and associated confidence limits are shown, derived from all the responses obtained during the three field trials described in Chapter I. It will be seen that the upper limit of the 'Satisfied' category intercepts the lower 90% confidence limit at 41.6 dB. The lower limit of the same category intercepts the other confidence limit at 31.4 dB, i.e. approximately 10 dB lower than the previous value.

This form of analysis suggests the existence of a tolerance zone which could explain many of the discrepancies in opinion which were noted during the preliminary visits to health centres. It also appears to correlate well with the results of case studied reported in subsequent chapters.

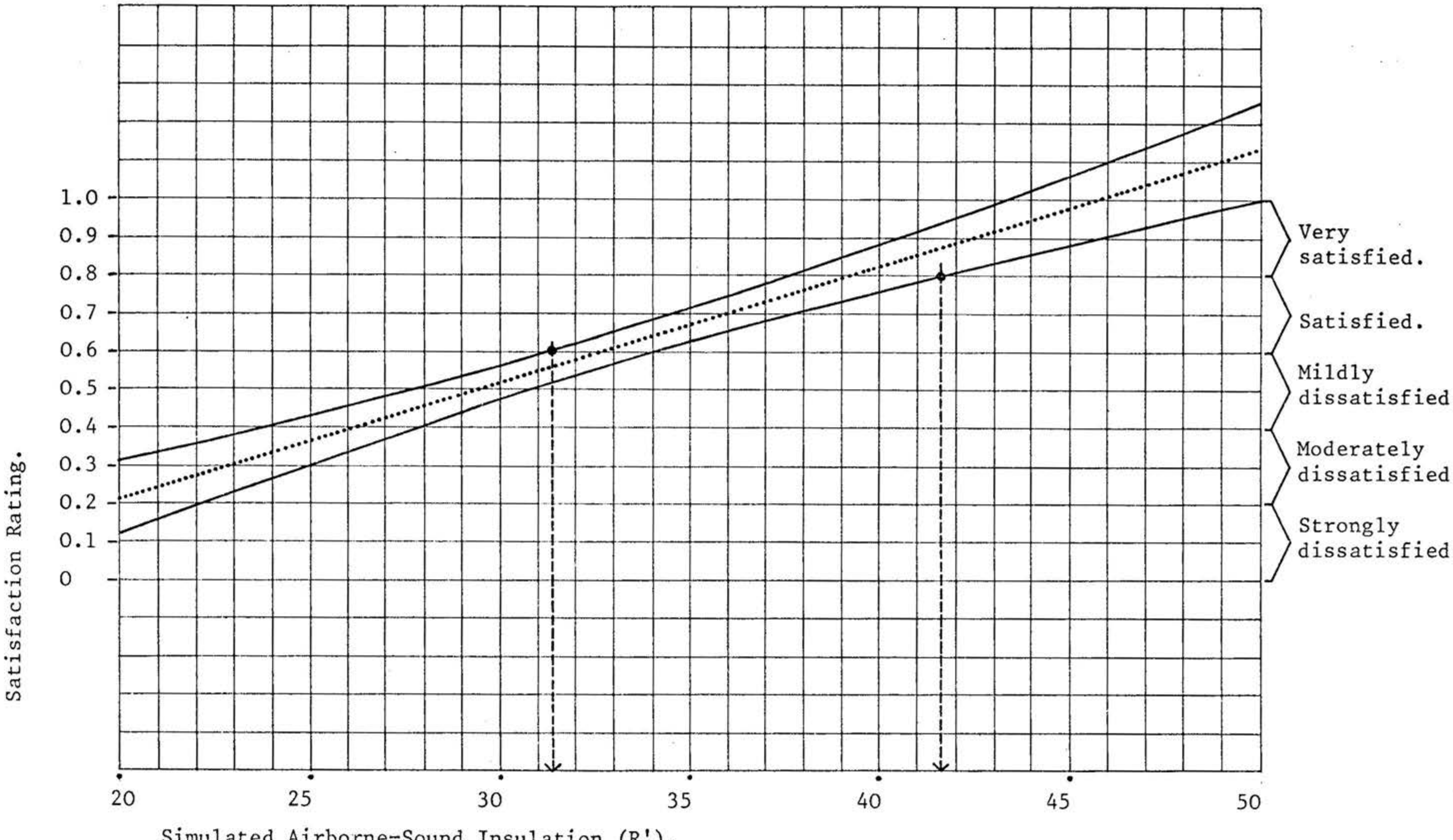


FIG 2.14 90% CONFIDENCE LIMITS ESTABLISHED BY FIELD TRIALS - INTERNAL NOISE LEVEL $\overline{\overline{<}}$ 35 dBA L_{50}. ROOMS CARPETED AND WITH ABSORBENT CEILINGS.

III DETERMINING THE NOISE CLIMATE

3.1 General.

The results of experiments reported in the previous chapter support the general hypothesis that the insulation required to provide speech privacy is inversely proportional to the ambient noise. The effect of the ambient noise may be less marked however, between consulting rooms with identical noise climates, than between consulting rooms and waiting areas. This is due to the modification of the voice level by the ambient level.

In the consulting room the masking level will usually be dictated by traffic noise intruding through the window. If the latter is relatively small in area the external wall should be regarded as a composite partition. In waiting areas the internal sources may be more significant in most locations, although traffic noise through windows and roof lights can still play an important role.

Noise levels of 45 - 55 dBA are quoted for consulting rooms in the outpatient departments of various hospitals by Rowland et al.[47] Extensive measurements have also been carried out by Orr[48] for diverse locations in hospitals and associated buildings. Typical levels classified as satisfactory range from 32 dBA for speech therapy, 35 dBA for a health clinic, 38 to 48 dBA for conference rooms, 44 - 54 for private offices and 58 dBA for an enquiries office adjacent to a public area. Levels above those quoted tend to be classified as unsatisfactory by room occupants.

3.2 Field measurements.

To provide more specific data for background noise levels in consulting rooms and waiting areas, systematic measurements of the noise climate were undertaken in the two health centres at Woodside and Dumbarton.

The first complete set of measurements was carried out at Woodside. As a preliminary, a portable sound level meter was used to take spot measurements throughout the building during the course of a typical working day. These indicated that L_{50} dBA levels for consulting rooms were of the order of 28 - 37 (34 - 51 dBA with windows slightly open, depending upon the orientation of the window facade). Levels in corridors and waiting areas generally ranged from 40 - 55 (one consulting and examination room suite was in use as a temporary typing pool; in this case the levels in the adjacent corridor ranged from 51 - 64). The highest levels, 49 - 64 dBA, were recorded in the region of the reception desk.

To provide further information about longer term variations a more permanent system of instrumentation was installed. An omnidirectional microphone was suspended approximately 3 metres above the second floor roof level, in a central position, to integrate all external noise.

In this particular building the individual practice waiting areas are interconnected forming one large extended area adjacent to the reception desk (see Fig 3.1).

A second microphone was mounted in this waiting area, again in a central position and approximately 1 metre below the ground floor ceiling level. The latter position was sited away from seats, thereby reducing the possibility of recording conversations at an audible level. The microphone therefore tended to integrate the various

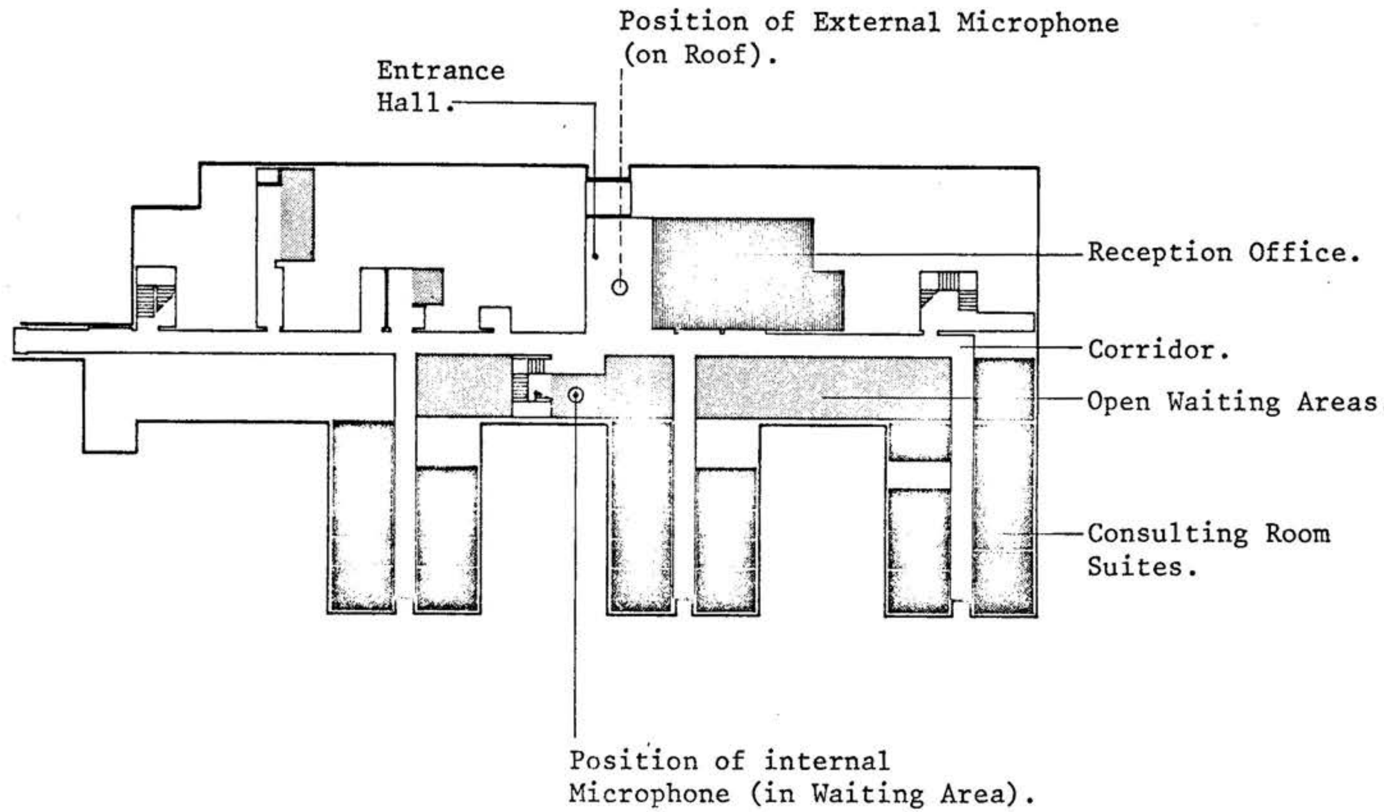


FIG 3.1- WOODSIDE HEALTH CENTRE, GLASGOW (GROUND FLOOR ZONE PLAN).

sounds forming the background noise in the waiting areas; the overall effect being to minimize the direct sounds and maximize the indirect ones.

The output from the microphones was taken via preamplifiers to a central twin-channel tape recorder, programmed with time switches to make a 40 second recording in every twelve minutes throughout the working day. The tape was analysed using a dBA weighting network and a statistical distribution analyser to establish the L_{10}, L_{50} and L_{90} levels. The results are presented in table 3.1.

A similar set of measurements was obtained in the Dumbarton health centre. In this instance however the plan form is radically different from that of Woodside; the individual practice waiting areas are separated and distributed throughout the building (see Fig 3.2). Preliminary sound level readings, again using a portable meter, indicated that although sound levels were of the same order as those of Woodside, greater variations occurred in different waiting areas. The procedure adopted therefore was to establish a sampling routine involving measuring stations distributed throughout the building. A portable tape recorder was connected to a sound level meter and deployed at approximately three minute intervals throughout five typical working days.[49] The duration of individual recordings was approximately 90 seconds out of which a 40 second period, as in the previous case study, was used for the statistical analysis.[50] The results are presented in Table 3.2.

The third building (Falkirk outpatients department) (Fig 3.3) was used for the first set of preliminary field trials (Chapter I) and many of the sound insulation measurements are quoted in subsequent chapters. A comprehensive analysis of background noise was not

	Internal (Waiting Area)	External (2 Metres above Roof)
Number of 40 second recordings made throughout one working week and subjected to statistical analysis. (N)	163	163
Arithmetic mean $(\bar{X})$	42.2	61.0
Variance $V\,[X]$	15.2	21.1
Standard deviation σ	3.9	4.6
Variance of mean $V\,[\bar{X}]$	0.09	0.13
Standard error of mean $S.E.\,[\bar{X}]$	0.31	0.36

TABLE 3.1 NOISE CLIMATE ANALYSIS - WOODSIDE HEALTH CENTRE.

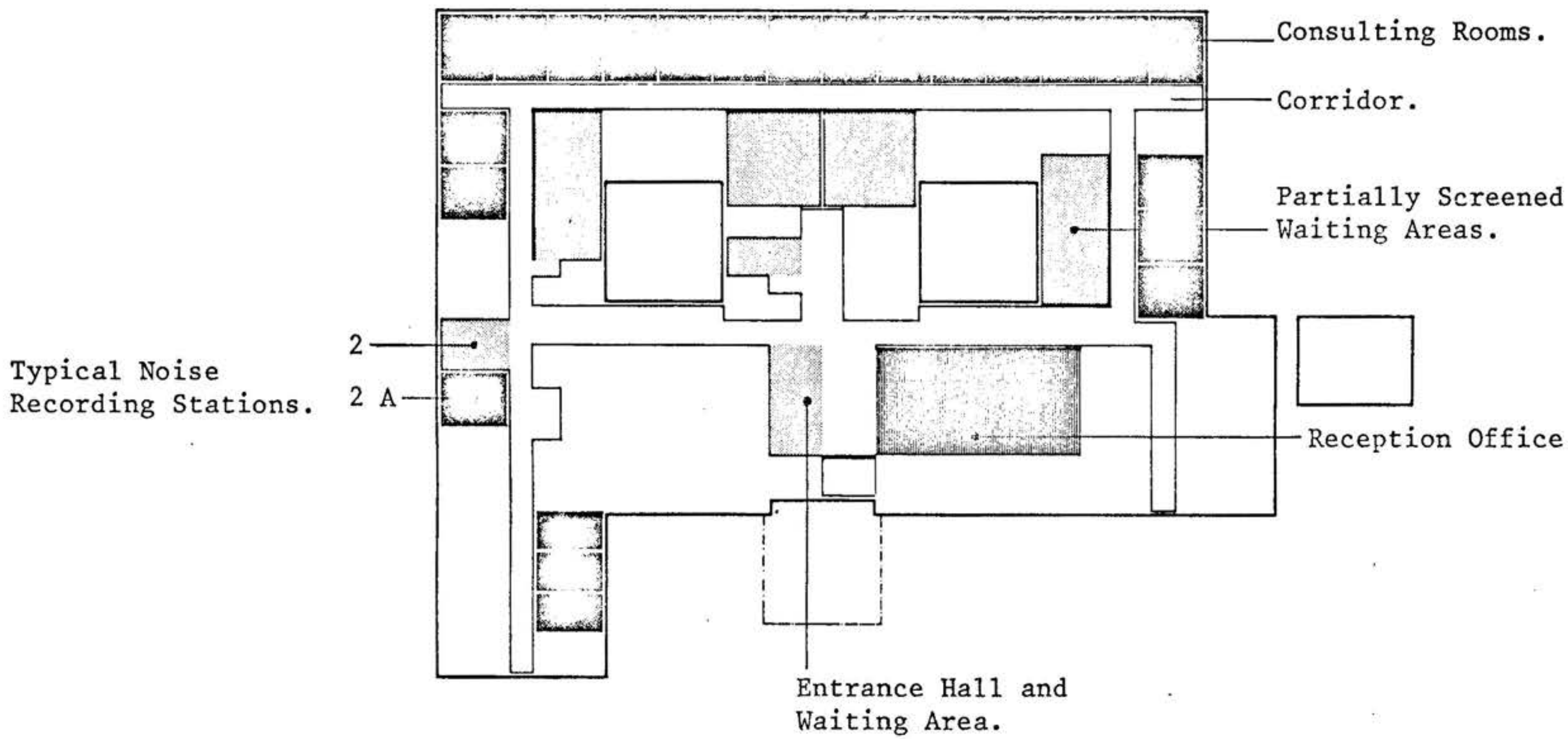
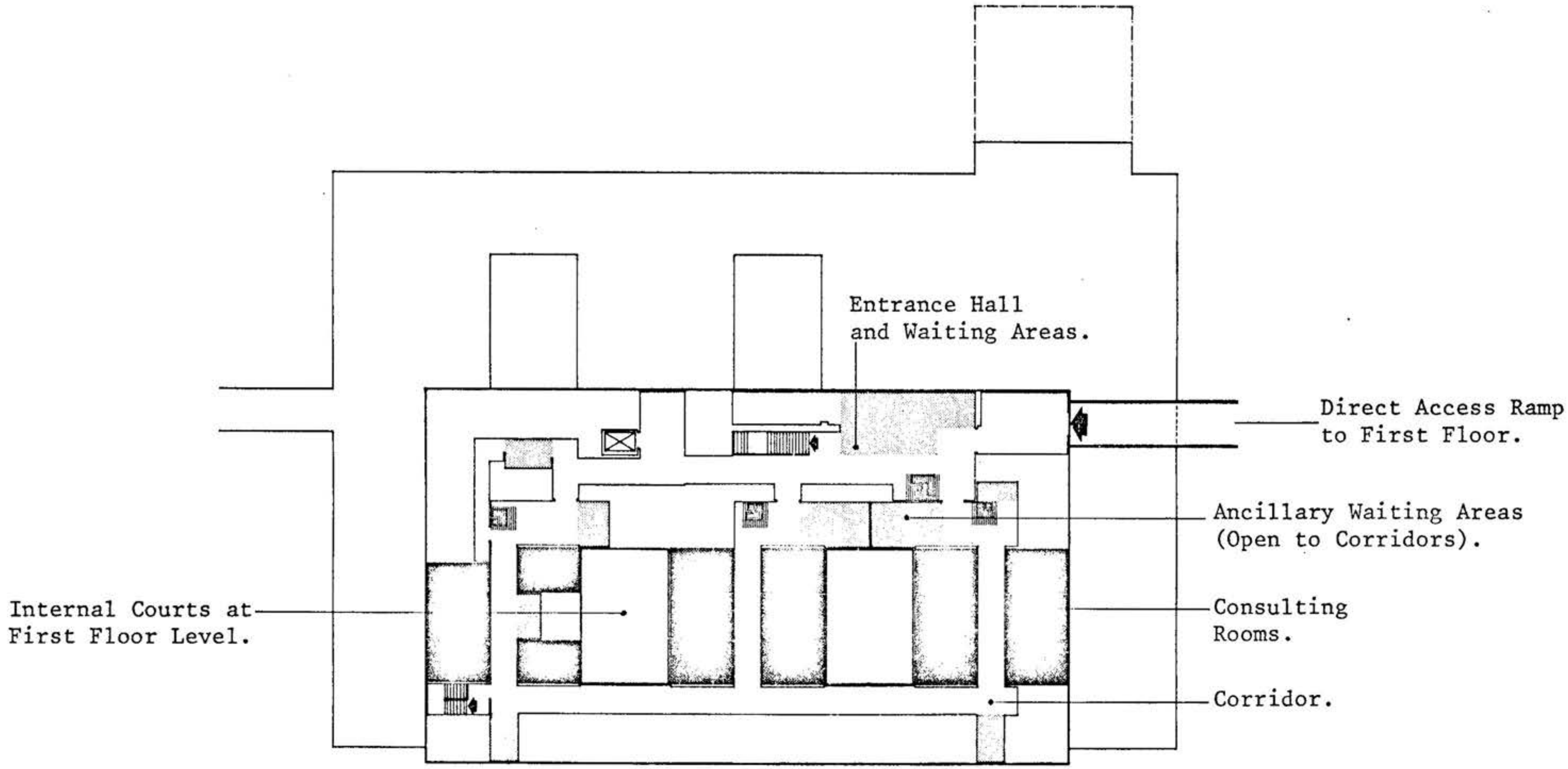


FIG 3.2 DUMBARTON HEALTH CENTRE (GROUND FLOOR ZONE PLAN).

FIG 3.3 OUTPATIENTS DEPARTMENT, FALKIRK ROYAL INFIRMARY (FIRST FLOOR ZONE PLAN).



General Location	General and Individual Practice Waiting Areas					
Station No	1	2	3	4	5	6
Number of 40 second recordings made throughout one working week and subjected to statistical analysis. (N)	19	20	19	20	20	20
Arithmetic mean $(\bar{X})$	42.6	37.0	38.1	33.0	31.9	35.1
Variance $V\left[X\right]$	11.27	48.28	14.20	8.05	22.12	12.45
Standard deviation σ	3.36	6.95	3.77	2.84	4.70	3.53
Variance of mean $V\left[\bar{X}\right]$	0.59	2.41	0.75	0.40	1.10	0.62
Standard error of mean. S.E. $\left[\bar{X}\right]$	0.77	1.55	0.86	0.63	1.05	0.79

TABLE 3.2 NOISE CLIMATE ANALYSIS - DUMBARTON HEALTH CENTRE. /continued.

General Location.	Consulting and Social Workers Rooms.					
Station No	1A	2A	3A	4A	5A	6A
Number of 40 second recordings made throughout one working week and subjected to statistical analysis. (N)	20	20	20	20	20	20
Arithmetic mean. $(\bar{X})$	30.3	34.4	31.5	30.5	29.9	29.6
Variance. $V\left[X\right]$	14.83	27.7	31.21	19.33	18.76	7.96
Standard deviation. σ	3.85	5.26	5.59	4.40	4.33	2.82
Variance of mean. $V\left[\bar{X}\right]$	0.74	1.38	1.56	0.97	0.94	0.40
Standard error of mean. S.E. $\left[\bar{X}\right]$	0.86	1.18	1.25	0.98	0.97	0.63

TABLE 3.2 continued. NOISE CLIMATE ANALYSIS - DUMBARTON HEALTH CENTRE.

possible in this instance, as the building was not occupied.[51] Spot measurements of the unoccupied building yielded readings for consulting rooms within the range of 27 to 32 dBA.

3.3 Results of field measurements.

The results from tables 3.1 and 3.2 for waiting areas[52] are summarized and included in the predictive method described in Chapter VI. It is possible of course that in some waiting areas traffic noise may raise the levels above those indicated by the table; in such cases the effect is to increase the factor of safety.

In consulting rooms the traffic noise will usually predominate; an initial decision has to be made, regarding the extent to which the external level should be reduced to approach the suggested optimum zone for internal levels of 30 - 42 dBA. Some form of calculation is required to predict the insulation of the external wall as a composite partition; the result of this can then be utilized in considering the sound insulation required between consulting rooms.

A spectrum analysis was also made, of tape recordings relating to stations 2 and 2A (Dumbarton health centre)[53], a subjective appraisal of all the internal recordings having suggested that these may be considered typical. The results of this analysis are illustrated in Fig 3.4.

3.4 Electronic masking noise.

Electronically or mechanically produced masking noise has been widely used to provide speech privacy in open plan offices. A comprehensive design method is provided by Beranek.[54] This solution has also been utilized to supplement the degree of sound insulation

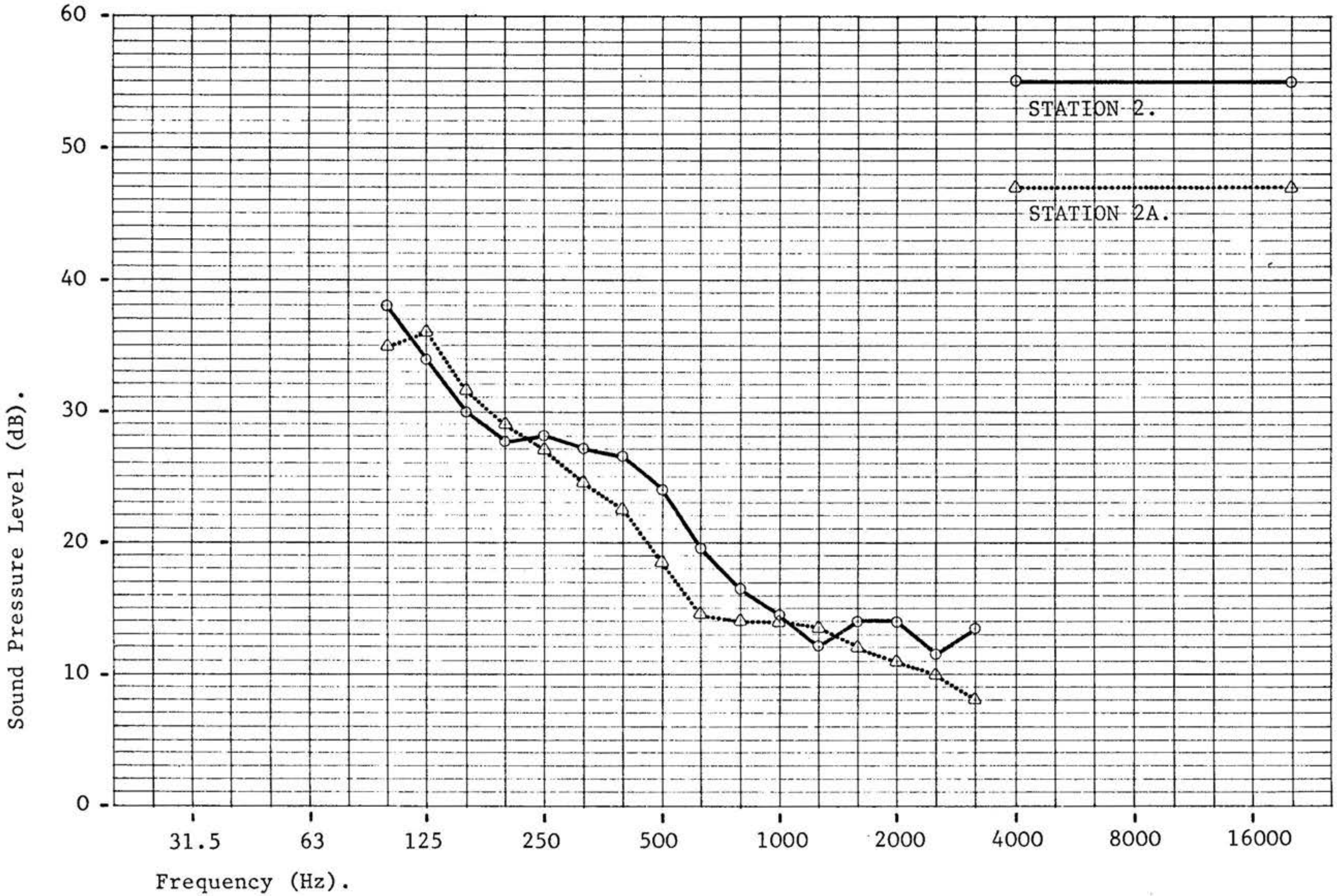


FIG 3.4 SPECTRAL ANALYSES OF INTERNAL NOISE. - STATIONS 2 AND 2A, DUMBARTON HEALTH CENTRE (1/3 OCTAVE BANDS).

between offices provided by a normal partition.[55]

The original design for the outpatients department at Falkirk incorporated medium weight flush doors in a standard form of plasterboard partition. Sound insulation measurements of this composite partition, were carried out and showed that the overall insulation (R') was approximately 26 dB. This result, coupled with the low ambient noise levels of 27 - 32 dBA, as measured in the empty building suggested that the occupants would be dissatisfied. Reference to B.S. C.P.3 Ch III, and the application of Young's method of prediction indicated that the degree of dissatisfaction could be extreme. On the other hand, the regression analysis of the field trials indicated only a mild reaction.

Three options appeared to be open if the degree of sound isolation was to be improved. The first was to upgrade the door and door seals, the second was to introduce artificial masking noise and the third was a combination of both.

The first solution was investigated experimentally in several locations in the building, using a very heavy 1 hour fire door to B.S. 459 Part 3 1951 with carefully fitted double Neoprene seals. The effect was to raise the overall insulation of the composite partition (R') to 30 - 31 dB. The field trials indicated that occupants' responses to this condition would lie above the Mildly Dissatisfied and just below the Satisfied criterion levels.

The laboratory experiments showed that the same degree of sound isolation could have been achieved by artificially raising the ambient level by approximately 7 dB to 42 L_{50} dBA, assuming an initial reference level of 35 dBA for the occupied room. The field trials also indicated that this increase would be tolerated by occupants, although conditions for the use of telephone and stethoscope would deteriorate.

A cost comparison of the two alternatives showed that whereas the upgrading of the door construction could be achieved for approximately 20p for every square foot of consulting room area, the cost of the electronic masking system was of the order of 57p per square foot.[56,57]

The final decision, taken by the S.D.D. architects and S.H.H.D. medical advisors, was to upgrade the doors. It may be noted that this solution falls short of the more stringent standards suggested by the laboratory experiments. The acceptance of this degree of insulation for an outpatients department, by the medical advisors, probably reflects the relatively low standards of speech privacy which have been provided in the past, in this type of building. In addition, the fact that in the outpatients department the chances of a patient meeting an acquaintance are slight may have influenced the decision.

The overall degree of sound isolation resulting from combined use of very heavy doors and a 42 dBA masking level would still be 7 - 8 dB below the laboratory criterion. Double doors would have achieved a similar result without affecting the background noise; the attendant inconvenience to doctors and nurses who may need to make frequent use of the doors was considered unacceptable.

IV SOUND INSULATION CHARACTERISTICS OF CLASP METAL-FACED PLASTERBOARD PARTITIONS.

4.1 General.

The basic reasons underlying the decision to employ the CLASP system of construction on a large scale, for health centres in Scotland, have been outlined in the preface. The purpose of this chapter is to present the results, carried out under both normal and controlled field conditions, of tests on this metal faced plasterboard partitioning system.

Although several isolated tests had been carried out previously on behalf of the Consortium, the conditions for these were not typical of those found in health centres or hospital outpatient departments. More comprehensive information was therefore required, to evaluate the performance on a statistical basis and to provide supplementary data regarding the effect of composite partitions and flanking transmission.

The latter was considered of particular importance, as ancillary elements such as plenum barriers, suspended ceilings and doors usually combine to establish a limit to performance in the field. Frequently, the data supplied by the manufacturer or independant laboratory does not allow for flanking transmission; a similar lack of detail about methods of construction and standards of workmanship often means that test results are misinterpreted by the architect.

The change from imperial to metric dimensions occurred during the course of this section of the research, associated with the transformation from CLASP Mk 4B to Mk 5 details of construction.[58] The Mk 4B system formed the basis for the initial sample as no completed Mk 5 buildings existed in Scotland at that time. The results with regard to the shape of the insulation spectrum were then used in the laboratory experiments reported in Chapter II. A small Mk 5 prototype construction erected at Paisley Royal Infirmary was used to obtain supplementary information under controlled conditions; to predict possible differences in performance between Mk 4B and 5; to gain accurate data about the effect of flanking transmission via the ceiling void and to study the effect of inserting various doors and door seals.[59] The latter investigation was considered of special significance as the first series of tests had shown that the performance of a standard CLASP door set was totally inadequate for speech privacy.

Field measurements of plastered 4½" brick walls, again both with and without doors were carried out in a health centre of traditional construction and coupled with similar measurements of a standard form of plasterboard and metal stud partition provided controls against which the CLASP element could be judged.[60]

The results of all test sequences are listed in sections 4.2, 4.3 and 4.4. In the subsequent chapter, comparisons are drawn, with particular reference to grading procedures in current use in Britain, Europe and the U.S.A. Comprehensive details of all the test locations are given in Appendix IV and a brief description of measurement procedures in Appendix Vb.

A number of ancillary tests were carried out which are not listed in the following chapter; due to circumstances within the buildings, the tests could not conform to standard procedures therefore to quote the results might be misleading.

One such test was between rooms and corridors to establish the performance of the standard CLASP doorset. The value obtained for the sound insulation was approximately 20 dB, well below an acceptable standard for buildings designed for speech privacy.

Many types of proprietary doors are available, which, together with special frames and ironmongery, appear to provide a good degree of sound insulation. Usually the cost of these is prohibitive within large buildings which have to conform to rigid cost limits; in addition the integration of non-standard details into the CLASP system can frequently cause considerable difficulties during both design and erection processes.

Lockwood and Pedder-Smith[61] have pointed out the benefits of variety reduction with respect to doors. The major factor influencing the sound insulation performance of the door is its overall weight. Within both health centres and outpatient departments heavy doors are used, as fire checks and also to prevent harmful radiation from rooms used for radiography. Both types of door are constructed to appropriate British Standards.

The lead lined door used to impede X-rays would seem to hold the greater promise due to the high loss factor of the lead membranes. The asbestos cored 1 hour fire check door is of similar overall weight although the loss factor is probably less. The lead cored door is more expensive than the latter however and in practice the door seals usually prove the limiting factor. The asbestos cored doors were therefore used as the basis for tests, and following these tests were specified generally.

The standard CLASP Neoprene door seals were unsatisfactory. Double seals were incorporated using proprietary but readily available sections. The only other non-standard elements were intermediate door frame linings formed of hardwood.

The standard form of plasterboard partition incorporating folded steel studs, as tested in section 4.4, is of equivalent overall cost to the CLASP partitions. It is widely used as a lightweight non-loadbearing and relatively low-cost method of construction and therefore provides a useful yardstick.

4.2 Field tests on the Mk 4B partition.

This section describes the first series of tests (designated A) to determine the sound insulation properties of the metal faced plasterboard partition as incorporated in the Mk 4B system. Detailed drawings of typical junctions are not provided but are generally similar to those of the Mk 5 system as included in Appendix IV.

4.21 Locations for test series A.

At the beginning of this series the only Mk 4B buildings accessible in Scotland were school extensions in East Lothian, namely the Knox Academy at Haddington and the Ross High School at Tranent.[62] A detailed inspection of these showed that the majority of partitions, especially those between classrooms, were not suitable for test purposes due to the fact that heavy fittings such as blackboards, were either fixed directly on or in close proximity to them thereby increasing both the stiffness and effective mass of the partition. An additional factor was the size and furnishing of adjacent rooms; the consulting room is relatively small and contains considerably more absorption per unit area than the typical classroom and although normalizing procedures are available to account for these differences there is not as yet universal agreement as to the formula most applicable to both school and health buildings. Test rooms were therefore chosen which were similar in character to consulting rooms, thereby minimising errors which might arise due to the normalizing process. (A detailed exposition of the actual normalizing procedure adopted is given in Chapter V). The six test locations which were finally selected from these two schools are shown in plan form in Appendix IVb. Shortly after this initial sequence was completed a Mk 4b health centre at Dumbarton became available for two additional tests on partitions without doors and these are also included.

It will be noted that, despite the selection procedure, there are still considerable variations in room size, in ratio of area of partition to receiving room absorption and in flanking conditions at the window wall. Associated variations in these results should therefore reflect the statistical spread to be anticipated in health centres and outpatient departments, or indeed between any rooms of similar character to consulting rooms.

4.22 Results of tests.

The airborne sound insulation (R')[63] for these eight partitions is plotted against frequency in Fig. 4.1. The average result of all tests is shown on the graph and ±1 dB standard deviation indicated by the heavy solid vertical lines. These means and standard deviations are also listed in table no 4.1.

The average sound insulation for all tests at all frequencies is

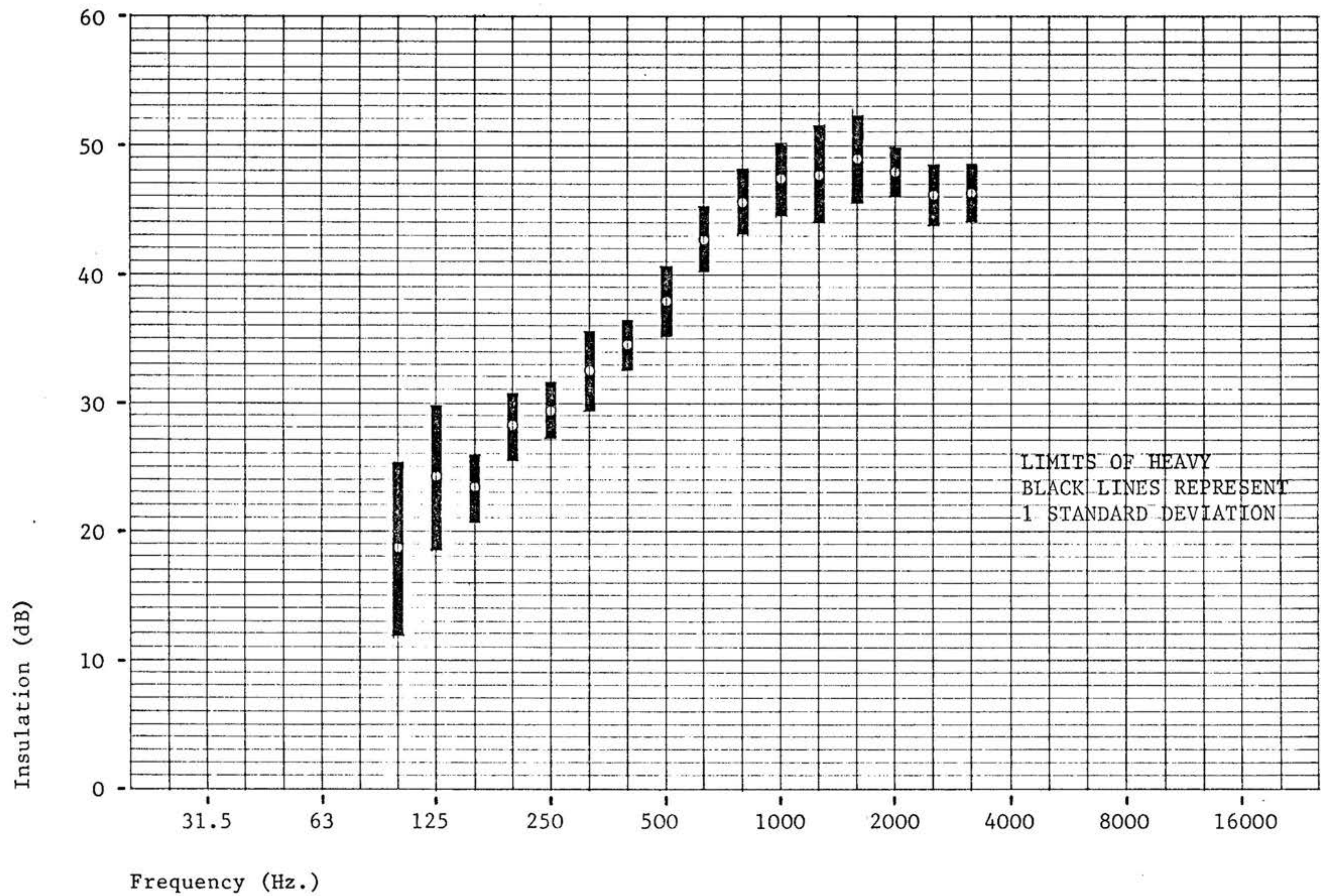


FIG. 4.1 AIRBORNE SOUND INSULATION (R') OF THE CLASP MK. 4B PARTITION.

Frequency (Hz)	Mean of all tests	Standard Deviation	
		s	σ
100	18.6	6.7	(7.2)
125	24.2	5.6	(6.0)
160	23.3	2.6	(2.5)
200	28.1	2.6	(2.8)
250	29.3	2.2	(2.4)
315	32.4	3.1	(3.3)
400	34.5	2.1	(2.1)
500	37.9	2.8	(3.0)
630	42.7	2.5	(2.7)
800	45.6	2.5	(2.7)
1000	47.3	2.8	(3.0)
1250	47.7	3.7	(4.0)
1600	48.9	3.3	(3.6)
2000	47.9	1.9	(2.1)
2500	46.1	2.3	(2.4)
3150	46.3	2.2	(2.3)
Average	37.6 dB	3 dB	(3.3)

TABLE 4.1 AIRBORNE SOUND INSULATION (R') dB OF THE CLASP MK 4B PARTITION.

37.6 dB and the standard deviation is ± 3 dB. Thus the expectation in the field is that in approximately 84% of all locations the effective insulation will be equal to or better than 34.3 dB, providing that the area of the partition is 10 sq. metres and the reverberation time in the receiving room 0.5 sec.

4.23 Workmanship

Generally all work appeared to meet the specification laid down by the Consortium,apart from the construction of the plenum barrier. (The latter is formed from plasterboard sheet positioned directly over the partition in the void formed by the suspended ceiling.) The specification for this component called for plaster on scrim caulking around all edges and also around holes cut to admit conduit and other services. This sealing did not appear to be provided in any of the test locations, although an exhaustive examination was not possible in every case. All vertical joints between individual partition modules were tightly sealed by means of the standard preformed plastic coated metal strips with the exception of the junction between the edge of the partition and window wall mullions. At this latter point small gaps were visible in most instances and their probable effect is evaluated in section 4.24.

4.24 Variations due to flanking transmission at the external wall.

The internal partition to external wall junction takes three different forms in this test series.

In the case of tests nos 1, 4 and 5 the partition is flanked on both sides by windows extending from a cill height of 3'6" to the underside of the suspended ceiling. The edge of the partition is fixed adjacent to a wooden window mullion, a small air gap being visible at this point with a maximum width of approximately 1/16". This latter dimension varies at different times depending upon moisture content and thermal differentials in the mullion.

In tests nos 2, 3 and 6 the partition is flanked on both sides by the external wall returning approximately between 1'0" and 2'0" on plan, in location no 2 and 3'0" in nos 3 and 6.

In tests nos 7 and 8, the partition is flanked on one side by a wall extending from floor to ceiling and 3'0" on plan and on the other by an external wall return of 6'0". In this instance, air gaps existed from floor to ceiling at both window mullions, the approximate maximum width of the air gap being 3/32".

The means of the airborne sound insulation for each of these sub-groups are plotted in Fig. 4.2. The marked variations shown by the three graphs at frequencies between 500 hz and 2 K/hz and particularly at 1.6 K/hz are most probably due to the existence of these air gaps at the mullion, combined with variations in the fitting of the plenum barrier. Means and variations of means are listed in table 4.2.

The difference in insulation for the second and third groups is 4.3 dB, this being primarily attributable to variations in sealing at the external wall junction.

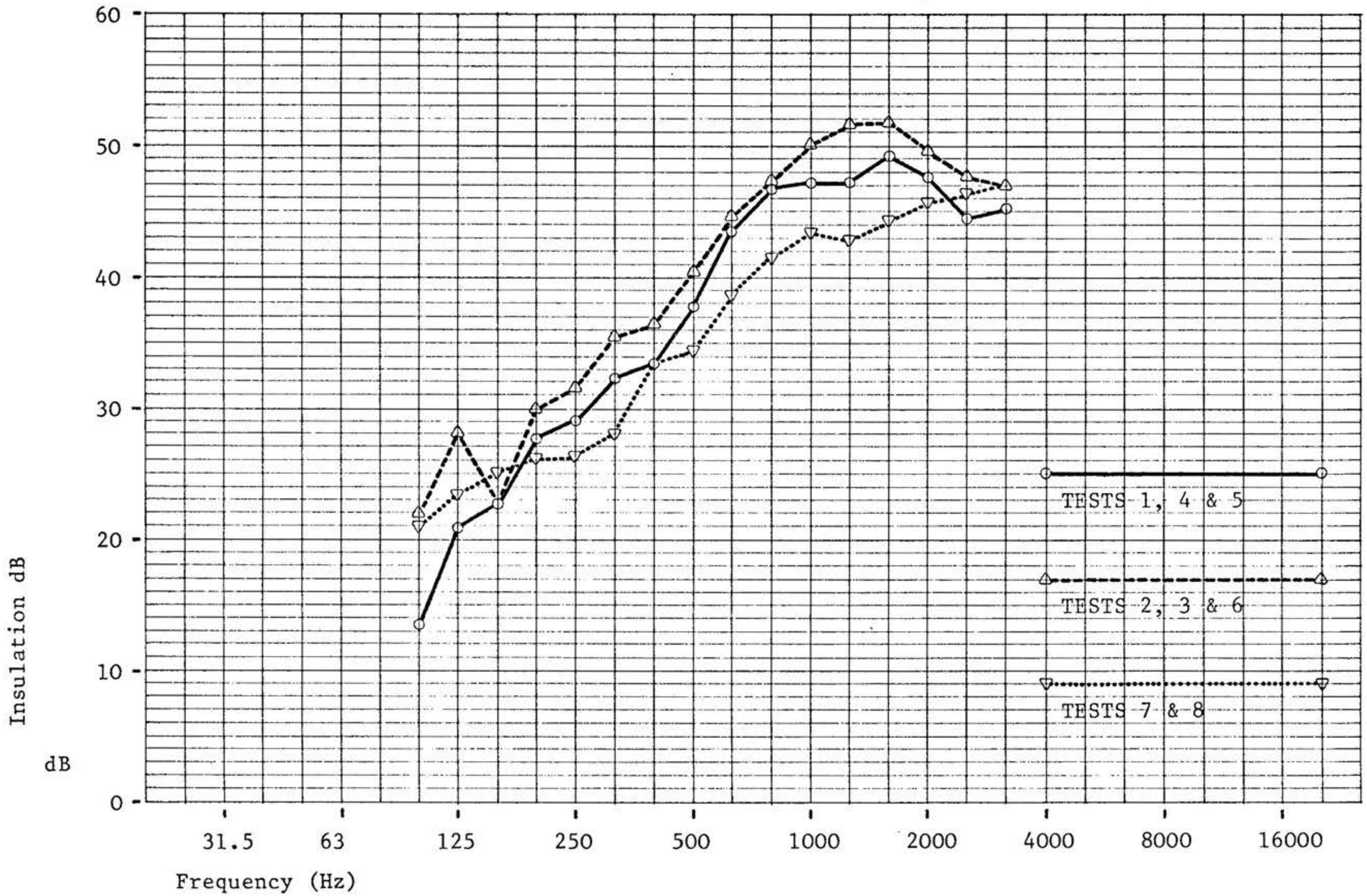


FIG 4.2 THE EFFECT OF SMALL AIR GAPS - MK 4B PARTITION.

Frequency (Hz)	Mean Tests nos A1, A4 & A5	Mean Tests nos A2 A3 & A6	Mean Tests nos A7, & A8	Maximum variation of mean.
100	13.5	21.9	21.0	8.4
125	20.8	28.0	23.5	4.5
160	22.7	22.8	25.1	2.4
200	27.6	29.9	26.1	3.8
250	29.1	31.4	26.3	5.1
315	32.3	35.5	28.0	7.5
400	33.4	36.4	33.3	3.1
500	37.7	40.4	34.5	5.9
630	43.4	44.6	38.7	5.9
800	46.7	47.2	41.6	5.6
1000	47.2	50.1	43.4	6.7
1250	47.2	51.5	42.8	8.7
1600	49.2	51.7	44.3	7.4
2000	47.6	49.6	45.7	3.9
2500	44.3	47.6	46.4	3.3
3150	45.1	47.0	47.1	2.0
Average sound insulation.	36.7	39.7	35.4	

TABLE 4.2 AIRBORNE SOUND INSULATION (R') dB OF THE MK 4B PARTITION. VARIATIONS DUE TO THE EFFECTS OF FLANKING TRANSMISSION.

4.3 Tests on the Mk 5 prototype at Paisley.

A second series of seven tests (designated B) was carried out in a small prototype building at Paisley General Hospital to determine both the effect of the plenum barrier and the sound insulation of the composite partition when the selected doors were inserted. The prototype was originally designed as a 'mock-up' to enable the Western Regional Hospital Board to study the actual building sequence for the system. Consequently, constructional details and flanking transmission paths were predetermined before the acoustic tests were planned. Plans, sections and details of the prototype are shown in Appendix IVa. No windows were incorporated.

A preliminary inspection revealed that the standard of construction, particularly with regard to the fitting of the suspended ceilings, the plenum barrier and several partition components was well below that of the Mk 4B sample. As a preliminary therefore the faulty components were replaced or re-aligned until the standard of construction was in accordance with the standard specification for Mk 5.

4.31 Sequence of tests.

The sequence and component configurations for the seven tests are shown in table 4.3. Constructional details and a specification for each test condition are provided in Appendix IVa.

4.32 Results of tests.

For the purposes of comparison these tests fall into two groups. Group 1, comprising tests nos B1, B2 and B7, is primarily concerned with the effect of the suspended ceilings and the plenum barrier. Group 2, comprising tests nos B3, B4, B5 and B6, provides

Test no B1	Partition without door. Plenum barrier removed. Standard ceiling.
Test no B2	Partition without door. Plenum barrier fitted. Standard ceiling.
Test no B3	Partition incorporating a single standard CLASP Mk 5 door set but with improved threshold detail. Plenum barrier fitted. Standard ceiling.
Test no B4	Partition incorporating single ½ hour fire check door to B.S. 459 with special jambs and seals. Plenum barrier fitted. Standard ceiling.
Test no B5	Partition incorporating double ½ hour fire check doors to B.S. 459 with special jambs and seals. Plenum barrier fitted. Standard ceiling.
Test no B6	Partition incorporating single 1 hour fire check door to B.S. 459 with special jambs and seals. Plenum barrier fitted. Standard ceiling.
Test no B7	Partition without door. Plenum barrier removed. Asbestos plank ceiling.

TABLE 4.3 SEQUENCE OF TESTS ON THE MK 5 PROTOTYPE.

comparative data when various doors are inserted. The actual sequence of tests was dictated by practical considerations involved in changing from one test condition to another.

The results for Groups 1 and 2 are shown in Figs 4.3 and 4.4 and the airborne sound insulation data (R') upon which the graphs are based is given in tables 4.4 and 4.5.

4.33 Workmanship and flanking transmission.

In interpreting these results it should be borne in mind that these particular test circumstances are not strictly representative of either laboratory or field conditions. The degree of supervision given during the preparations for each test and the resulting standard of workmanship probably exceeded the normal for an actual building. On the other hand flanking transmission paths were present which were atypical of a laboratory test and therefore in this respect the test circumstances are more related to field conditions. The purpose of this test series was to produce accurate comparative data: if the results are used for prediction they should be regarded as the upper limits to be expected of any statistical sample which might be obtained under field measurement procedures.

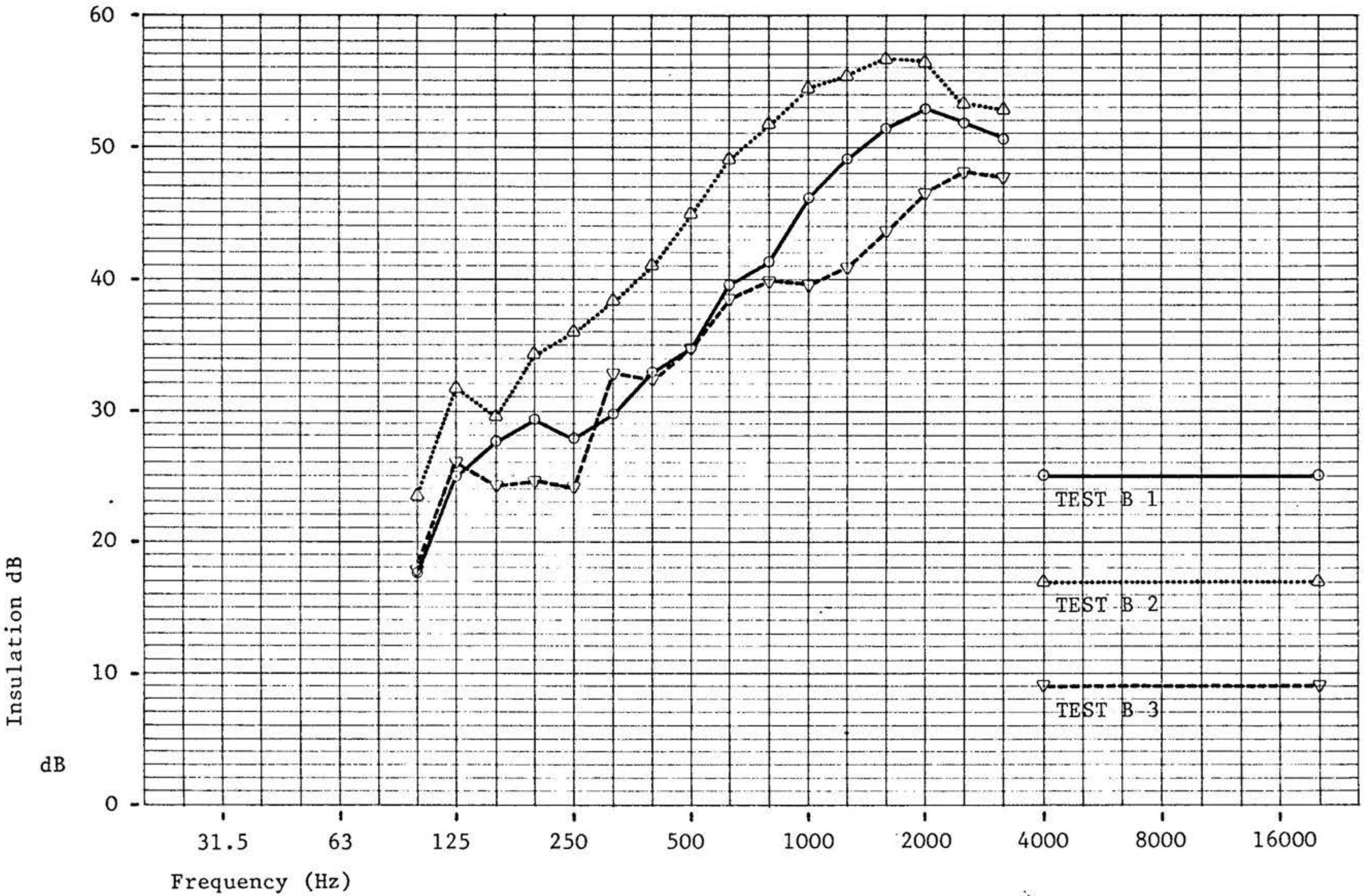


FIG 4.3 THE EFFECT OF A PLENUM BARRIER AND ALTERNATIVE SUSPENDED CEILINGS ON THE AIRBORNE SOUND INSULATION OF THE CLASP MK 5 PARTITION.

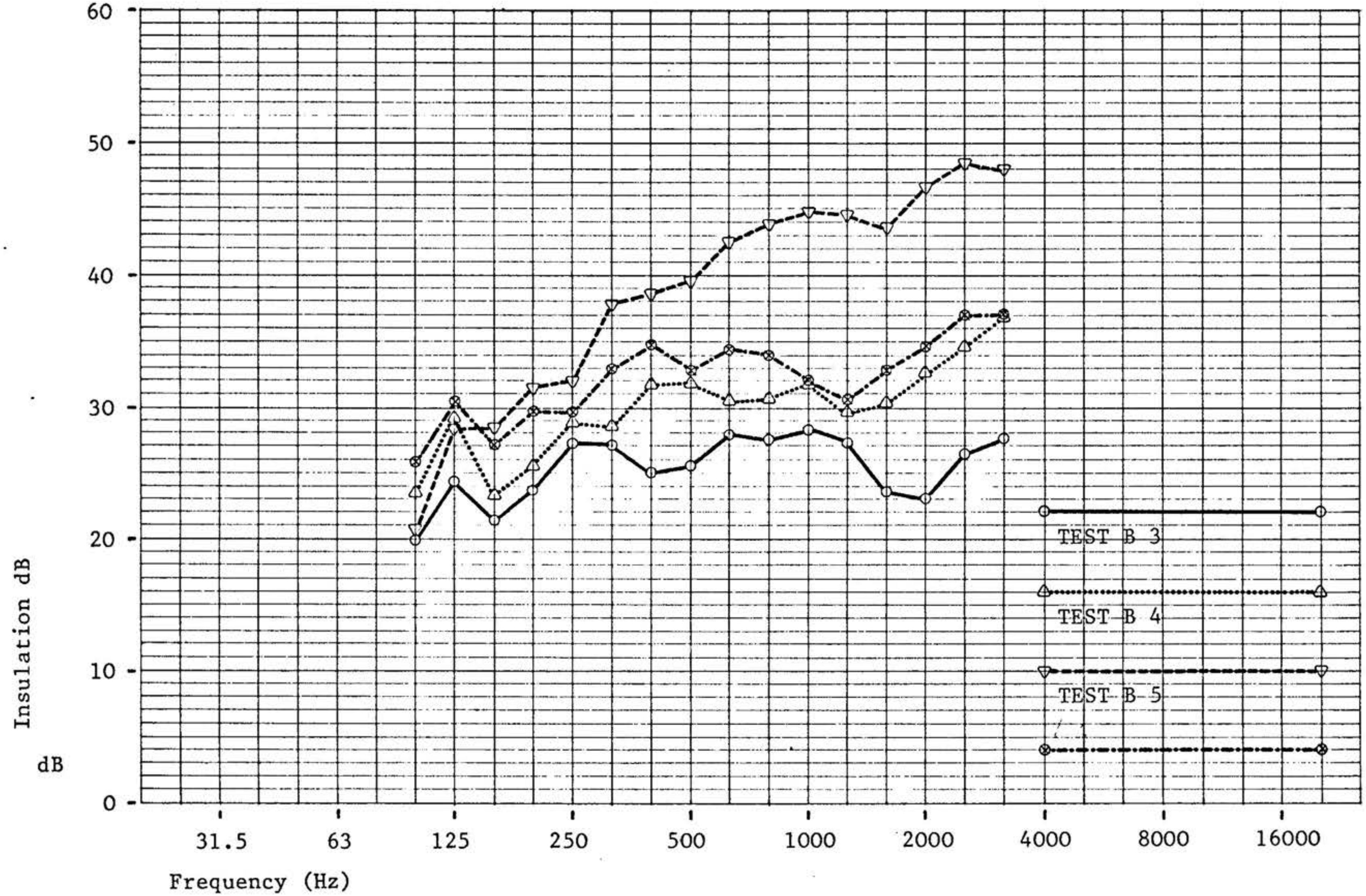


FIG 4.4 AIRBORNE SOUND INSULATION - MK 5 PARTITION (INCORPORATING ALTERNATIVE DOOR CONSTRUCTIONS).

Frequency (Hz)	Test no B1	Test no B2	Test no B7
100	17.6	23.5	17.9
125	24.9	31.6	26.0
160	27.5	29.5	24.3
200	29.3	34.3	24.6
250	27.7	36.0	24.2
315	29.7	39.3	32.9
400	32.8	41.0	32.5
500	34.7	44.9	34.8
630	39.5	49.0	38.5
800	41.2	51.7	39.9
1000	46.1	54.5	39.6
1250	48.9	55.3	40.9
1600	51.3	56.7	43.7
2000	52.9	56.4	46.4
2500	51.7	53.3	48.0
3150	50.7	52.8	47.6
Averages	37.9	44.3	35.1

TABLE 4.4 AIRBORNE SOUND INSULATION (R') OF THE MK 5 PARTITION, SHOWING THE EFFECT OF THE PLENUM BARRIER AND SUSPENDED CEILINGS.

Frequency (Hz)	Test no B3	Test no B4	Test no B5	Test no B6
100	19.9	23.4	20.7	25.8
125	24.3	29.1	28.3	30.4
160	21.3	23.2	28.4	27.0
200	23.7	25.5	31.4	29.8
250	27.1	28.7	32.0	29.7
315	27.0	28.5	37.8	33.0
400	25.0	31.7	38.5	34.7
500	25.5	31.8	39.6	32.8
630	27.8	30.5	42.4	34.4
800	27.4	30.7	43.8	34.0
1000	28.1	31.7	44.7	31.9
1250	27.1	29.7	44.5	30.5
1600	23.5	30.3	43.6	32.8
2000	23.0	32.6	46.6	34.6
2500	26.3	34.6	48.4	37.0
3150	27.5	36.8	47.9	37.0
Averages	25.3	29.9	38.6	32.2

TABLE 4.5 AIRBORNE SOUND INSULATION (R') OF THE MK 5 PARTITION, INCORPORATING VARIOUS DOORS.

4.4 Field measurements of a standard plasterboard partition.

The third series of tests (designated C) was carried out in the new outpatients department of the Falkirk Royal Infirmary on a standard form of double-skinned plasterboard partition. The partition components are supplied by British Gypsum and the specification was listed by the Department of Health and Social Security in 1970 under the CUBITH* system of elements (*Co-ordinated Use of Building Industrial Technology for Health Programmes). The CUBITH publication dealing with partitions (Manufacturers Data Base 3/1) suggests that the Hollow Partition Grade 1 (100 mm overall thickness - double skin) with a high-attenuation ceiling and no plenum barrier, should provide over 40 dB of insulation, or alternatively that the same partition carried up to the underside of the structural floor but with low-attenuation ceiling, should also provide 40 dB of insulation.

4.41 Test sequences C

Plans of test locations are given in Appendix IV. The overall sequence and component configurations for the five test groups are shown in table 4.6.

4.42 Results of tests.

The results of groups C2 and C3 (Fig 4.5) show the performance of the basic partition both with and without the plenum barriers. The actual airborne sound insulation (R') factors are presented in table 4.7.

The comparison of the data of test groups C1 and C2 (Fig 4.6) shows that the effect of inserting the half-hour fire door fitted with single Neoprene seals is to lower the overall insulation on

GROUP C1	Partitions incorporating ½ hour fire doors fitted with single seals. No plenum barrier.
GROUP C2	Partitions without doors. No plenum barriers.
GROUP C3	Partitions without doors. Plenum barriers fitted.
GROUP C4	Comparative tests of ½ and 1 hour fire doors to B.S. 459 Part 3 1951, both doors fitted with double seals. Plenum barriers fitted.
GROUP C5	Partitions incorporating 1 hour fire doors to B.S. 459 Part 3 1951, all doors fitted with double seals. Plenum barriers fitted.

TABLE 4.6 TEST SEQUENCES AT THE FALKIRK OUTPATIENTS DEPARTMENT.

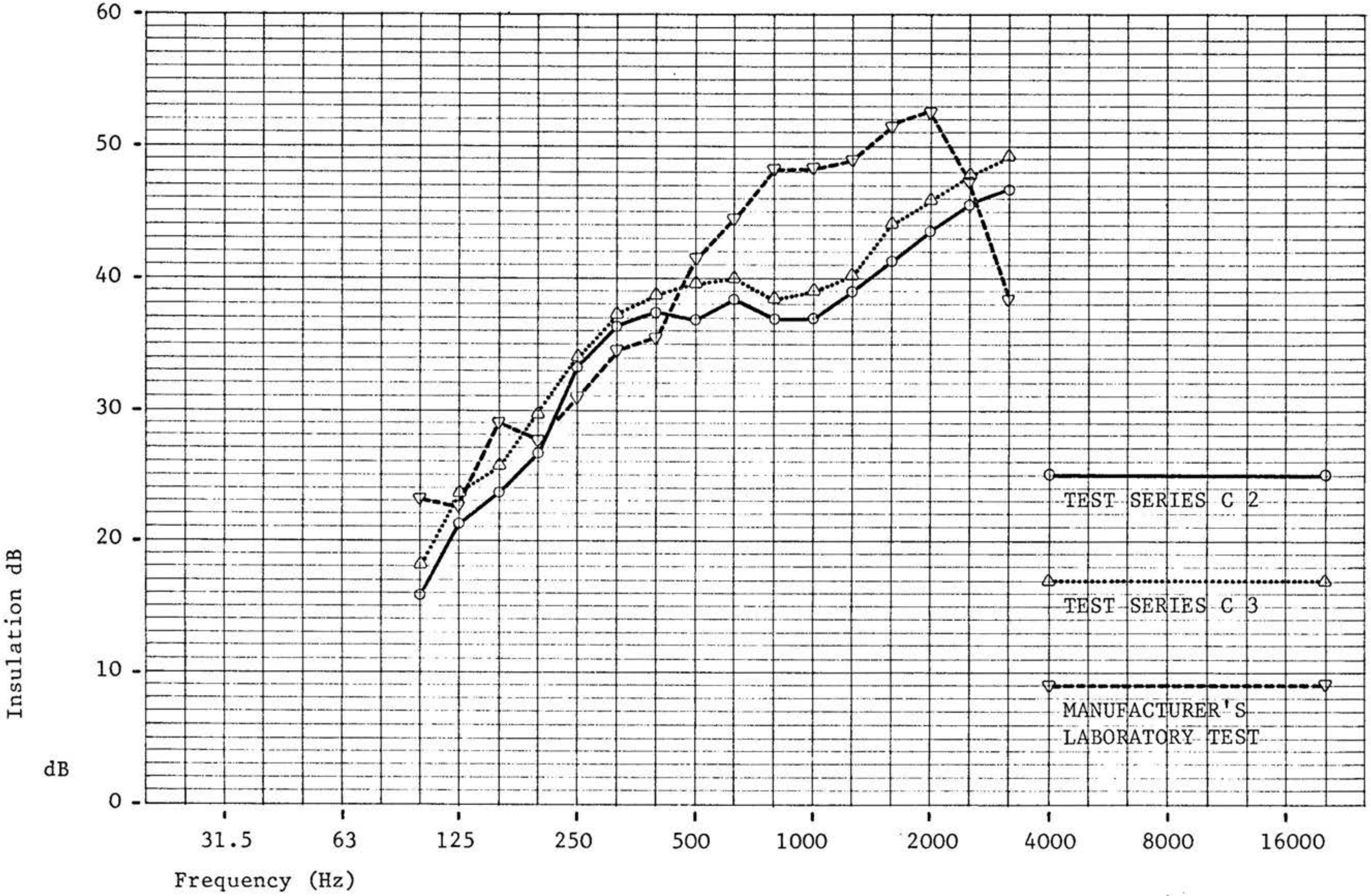


FIG 4.5 AIRBORNE SOUND INSULATION - STANDARD FORM OF PLASTERBOARD AND METAL STUD PARTITION (WITH AND WITHOUT PLENUM BARRIERS).

Frequency (Hz)	Test Groups C1	C2	C3	C4a	C4b	C5
100	13.5	15.7	18.1	17.6	18.5	15.8
125	16.6	21.1	23.7	18.9	18.9	18.7
160	17.1	23.6	25.7	19.4	19.2	18.0
200	22.7	26.6	29.7	27.2	23.3	23.6
250	25.3	33.2	34.0	27.9	24.7	27.3
315	26.1	36.3	37.2	25.7	27.7	29.9
400	25.9	37.3	38.7	28.4	30.1	29.7
500	27.1	36.9	39.6	30.9	33.1	30.6
630	28.7	38.3	40.0	31.1	34.5	31.9
800	30.0	37.0	38.4	31.7	37.6	34.0
1000	30.3	37.0	39.0	33.8	36.5	34.0
1250	31.4	39.0	41.2	34.1	36.5	34.2
1600	29.2	41.3	44.2	33.5	37.3	34.0
2000	27.5	43.6	45.9	33.2	38.6	36.5
2500	27.4	45.4	47.9	31.2	40.3	38.2
3150	29.6	46.7	49.2	34.0	40.9	39.5
Averages	25.5	34.9	37.0	28.9	31.1	29.7

TABLE 4.7 AIRBORNE SOUND INSULATION (R') OF THE STANDARD PLASTERBOARD PARTITION.

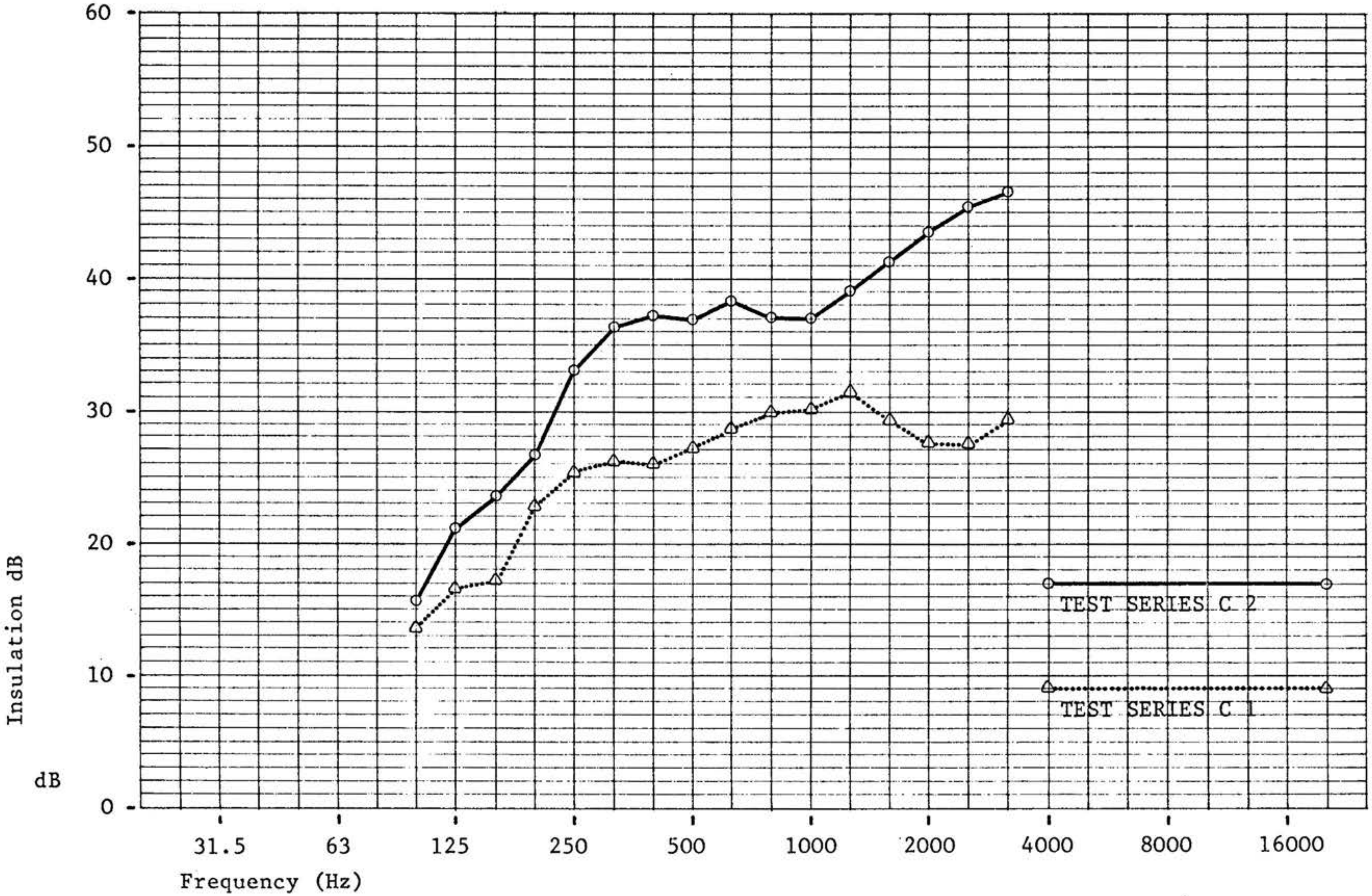


FIG 4.6 AIRBORNE SOUND INSULATION - STANDARD PLASTERBOARD PARTITION (INCORPORATING A ½ HOUR FIRE DOOR).

average by 9.4 dB. A similar comparison of groups C3 and C5 (Fig 4.7) shows that the very heavy 1 hour fire door fitted in partitions with plenum barriers lowers the insulation by 7.3 dB. Fig 4.8, (tests C4a and C4b) shows the results of a preliminary comparison of $\frac{1}{2}$ and 1 hour fire doors each fitted with double seals, prior to the final test sequence illustrated in Fig 4.7.

4.43 Workmanship.

The standard of workmanship was in general comparable with that found in the metal faced partition systems. Several exceptions must be carefully noted however in drawing comparisons with previous test series. In the Falkirk partitions the junction between the edge of the partition and the window mullion is carefully sealed in accordance with the specification. When the plenum barrier was inserted prior to test group no 3, scrim and plaster caulking was used similar to that called for in the CLASP specification and in this instance adequate site supervision ensured that this was carried out.

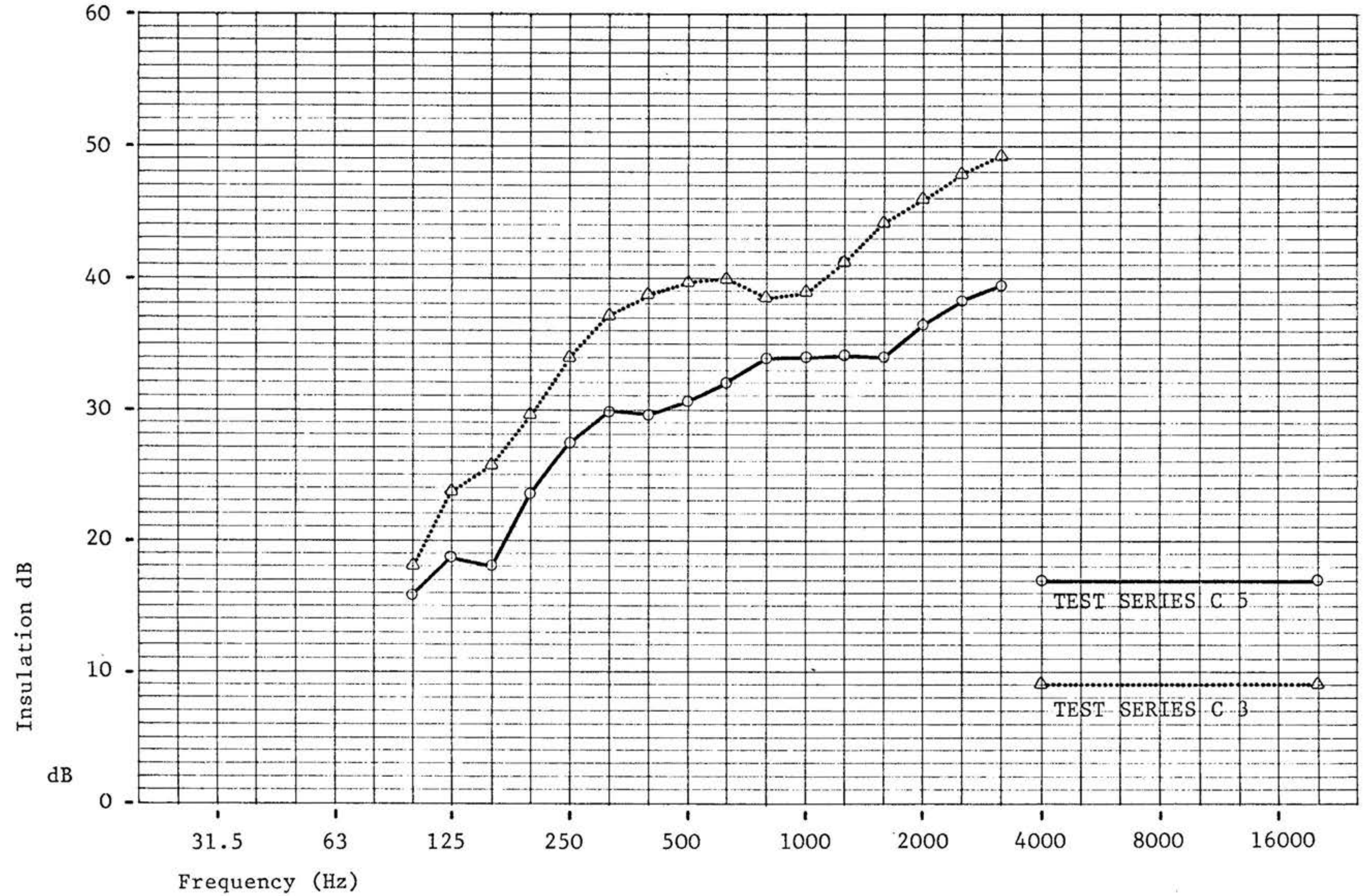


FIG 4.7 AIRBORNE SOUND INSULATION - STANDARD PLASTERBOARD PARTITION (INCORPORATING A 1 HOUR FIRE DOOR).

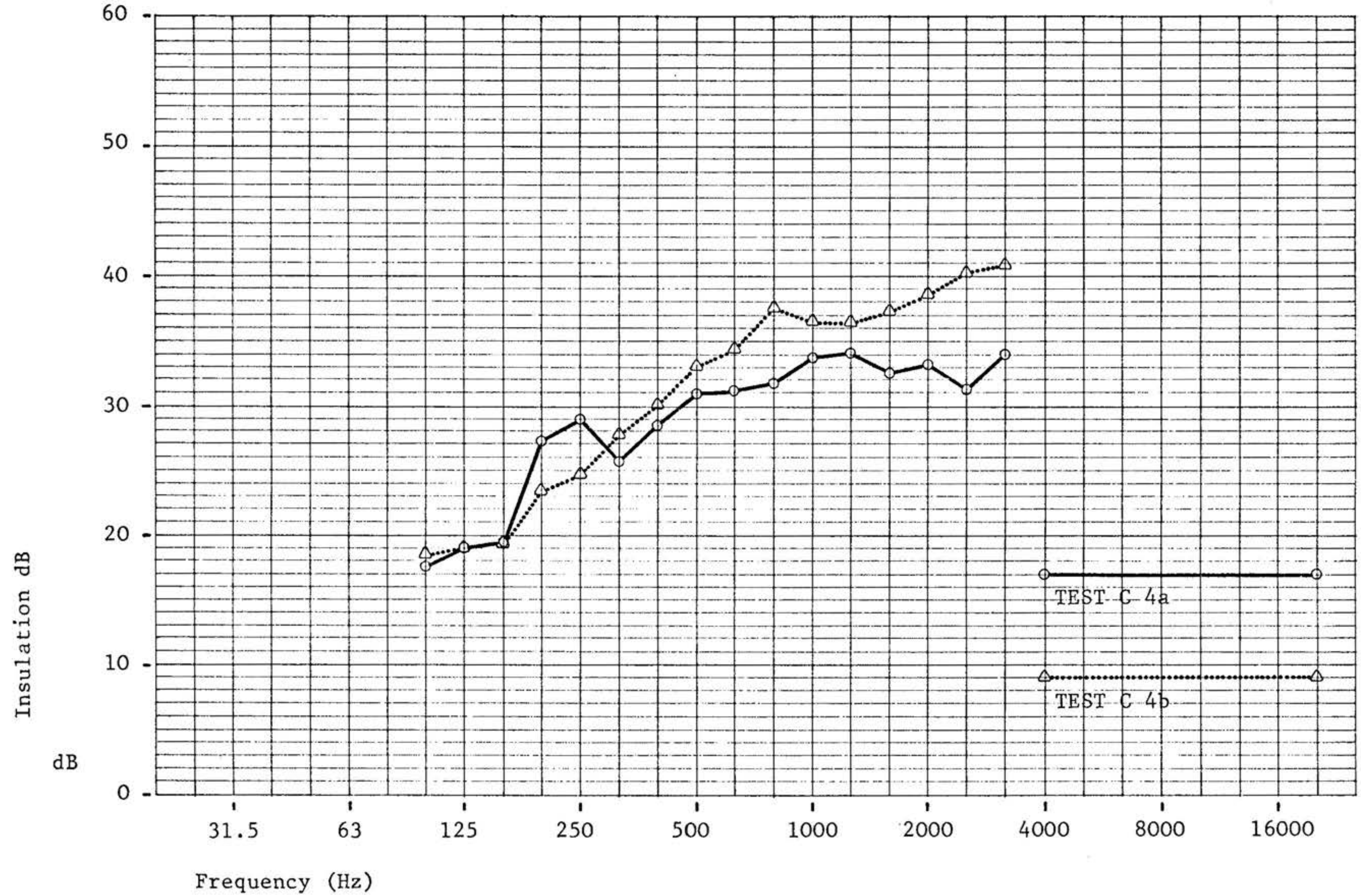


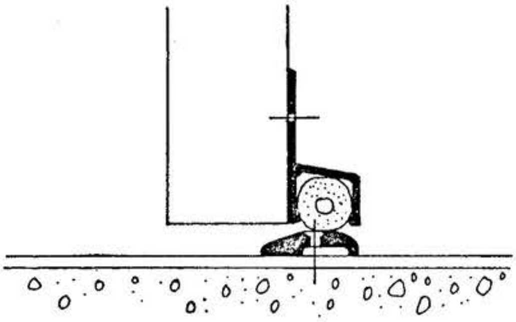
FIG 4.8 RESULTS OF PRELIMINARY TESTS ON ½ HOUR AND 1 HOUR FIRE DOORS - STANDARD PLASTERBOARD PARTITION.

4.5 Conclusions - Notes on workmanship and possible developments of the CLASP partitioning system.

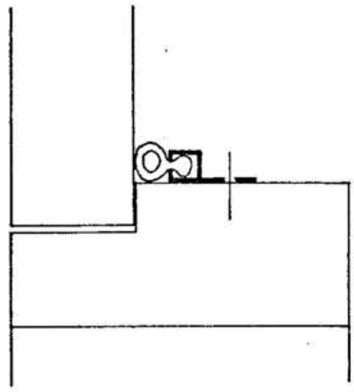
During the course of the experiments described in the preceding sections many practical points of detail were noted, regarding both standards of workmanship and also possible changes in the actual method of construction. The question of the importance of sealing in the region of window mullions and plenum barriers has already been referred to in Sections 4.24, together with the potential improvement in performance if such measures are carried out. This final section deals specifically with doors, door frames, door seals and suspended ceilings.

4.51 Doors and frames.

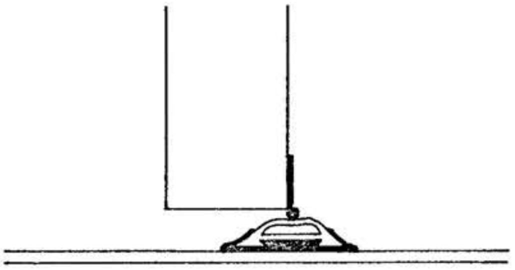
The standard CLASP door set consists of a relatively lightweight flush door hung in a folded steel frame. A special type of extruded Neoprene seal is inserted in a preformed groove at the jamb and head. In several of the buildings examined, there was a large air gap at the threshold, presumably intended to accommodate carpets and therefore unsatisfactory for thermoplastic tile and other thin floor finishes. Small air gaps were observed both between the frame and adjacent partition members and between the individual steel sections forming the composite door frame and fanlight. In test B3 the frame was assembled without obvious air gaps and a Neoprene and aluminium threshold was fitted (Fig 4.9a). At the first attempt at fixing, this was not in contact over its entire length and demonstrated an important principle in seal fixing. It is much easier both to obtain an effective seal and to see that the work has been done correctly if the detail is similar in principle to that shown in Fig 4.9b.



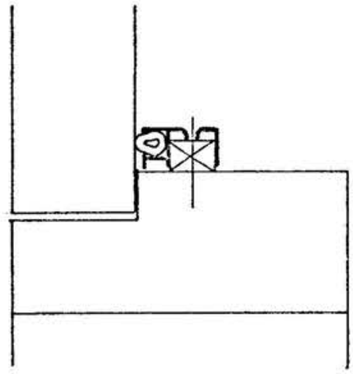
Section FIG 4.9a



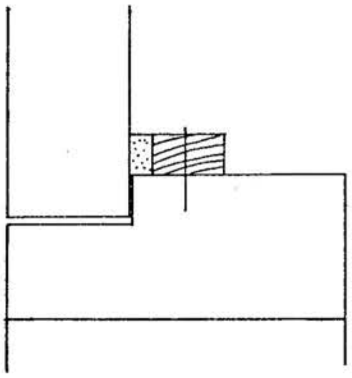
Plan FIG 4.9d



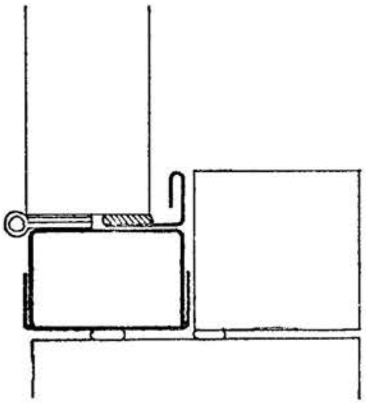
Section FIG 4.9b



Plan Fig 4.9e



Plan FIG 4.9c



Plan FIG 4.9f

FIGS 4.9a,b,c,d,e,f. ALTERNATIVE FORMS OF DOOR SEAL.

Jamb and head seals were designed on the same principle: first a cellular Neoprene strip was stuck to the rebate and a second seal fitted after the door was hung. If the door is slightly warped, as with most wooden doors, the first seal is unlikely to be in contact throughout. The second seal however can be fixed to follow the warp of the door and thus achieve a higher degree of efficiency.

The next critical factor is that of ironmongery. The pressure exerted by the seals on the door makes closing of the latter more difficult: this can be partially overcome by the use of a simple feeler gauge to ensure a light but reasonably constant pressure over the whole length of the seal, the most critical region occurring on the hinge side. Providing that a substantial form of ironmongery is specified and the partition and door frame do not flex, the door can be closed with a relatively light slam. This was demonstrated in the case of some twenty door sets at Falkirk. Theoretically the objections to any form of slamming action could be overcome by the use of ironmongery which closes with a cam action, although elegant ironmongery of this type is not easily obtained.

The CLASP ironmongery proved deficient for use with door seals of the type mentioned. The keeper plate assembly of the standard door set is very light and the fixing rivets quickly become loose, allowing the plate to move and thereby making it impossible to close the door against the seals. The door frames themselves are of light gauge metal and the insertion of an efficient seal in the rebate on the hinge side (Fig 4.9f) causes the actual frame to flex.[64] This effect, coupled with the loose keeper plate means that this detailing would be totally unacceptable in practice, although in the test situations efficient seals were established for the purpose of measurement. The deficiencies could however be overcome by redesigning the keeper plate assembly and making the door frame of a more substantial gauge of steel. Alternatively a substantial timber frame should prove entirely satisfactory although this would be a non-standard form of detail in the CLASP context.

Similar complications arose with regard to the overall stiffness of the partition when the very heavy 1 hour fire door was incorporated in the Mk 5 system. Placing the door-set in the standard module means that in some instances the supporting vertical metal stud may be approximately 300 mm from the actual jamb on one side. The latter therefore becomes dependent upon the external skins for overall stiffness and these are inadequate for this purpose. Some additional form of structural support is required particularly if a 1 hour fire door is to be used.

If the standard door-sets must be retained then the only way to ensure a reasonable sound insulation performance is by the use of double doors. Soft Neoprene seals may still be required in place of the standard ones and threshold sealing is also necessary. If possible the inner face of one door and the surfaces of the frame between doors should be lined with an absorbent material.

It will also be difficult to close both doors unless some method is devised for relieving air pressure between the doors without providing direct air paths to either. Holes drilled through the frame to link the space between the doors to partition or plenum cavities may be feasible in this respect.

4.52 Sealing strips.

Alternative forms of sealing strip are shown in Fig 4.9c, d and e. The simplest form as in (c) is probably the best, bearing in mind the fact that long term maintenance must be an important consideration. The more flexible form of aluminium housing for a Neoprene insert as shown in (d) is preferable to that of (e) as it can be more easily fitted to follow door contours. An additional objection to (e) is that the insertion of the Neoprene is unnecessarily complicated and can result in an uneven profile in relation to door contours and/or inadequate protusion from the face of the aluminium housing.[65,66]

4.53 Suspended ceilings.

The installation of suspended ceiling components also proved difficult as air gaps could not be completely avoided. In the case of the standard CLASP ceiling with exposed T-sections, tolerances between supporting ribs and panels varied, due to warping or dimensional discrepancies.

The most critical points occurred at the junction of the ceiling and partition components, particularly in the region of the door frame inserts. If the plenum barrier is not installed correctly and small air gaps occur between the ceilings and the head of the partition, the sound insulation is drastically reduced.

The importance of air gaps is also apparent in the comparison of tests B1 and B7. Although the latter ceiling was considerably heavier, the value for R' was lower due to bowing of the asbestos planks between inadequate fixing centres and unsatisfactory sealing around the ceiling perimeter.[67]

V INTERPRETATION OF FIELD MEASUREMENTS.

5.1 General.

In the previous chapter all results are tabulated as the Airborne Sound Insulation (R'). The experimental results illustrated in Chapter II, Figs 2.6 and 2.7 show that the insulation required for speech privacy can vary by 6 decibels even though the R' value remains constant.

Predictions following from articulation index theory, using the speech nomogram of Fig 2.1a, fit the experimental results at one point of the ambient noise range but not throughout. The complexities of obtaining and manipulating 1/3 octave data by the designer were discussed in section 1.8. In the following section the field results are studied in relation to alternative grading schemes which can be utilized to yield a single number index.

In the last two sections of this chapter allowances which may be required for flanking transmission, partition area and receiving room absorption are discussed, with reference to field measurements.

5.2 Grading of test results.

Results for test B2 (i.e. for the CLASP Mk 5 partition with plenum barrier) are plotted in Fig 5.1 relative to the grading curves for airborne sound insulation between dwellings. These curves were originally proposed by the Building Research Station and subsequently adopted as the basis for building regulations[68]. It may be seen that the performance of the Mk 5 partition falls short of Grade II by a cumulative deviation of 41 dB, this being greater

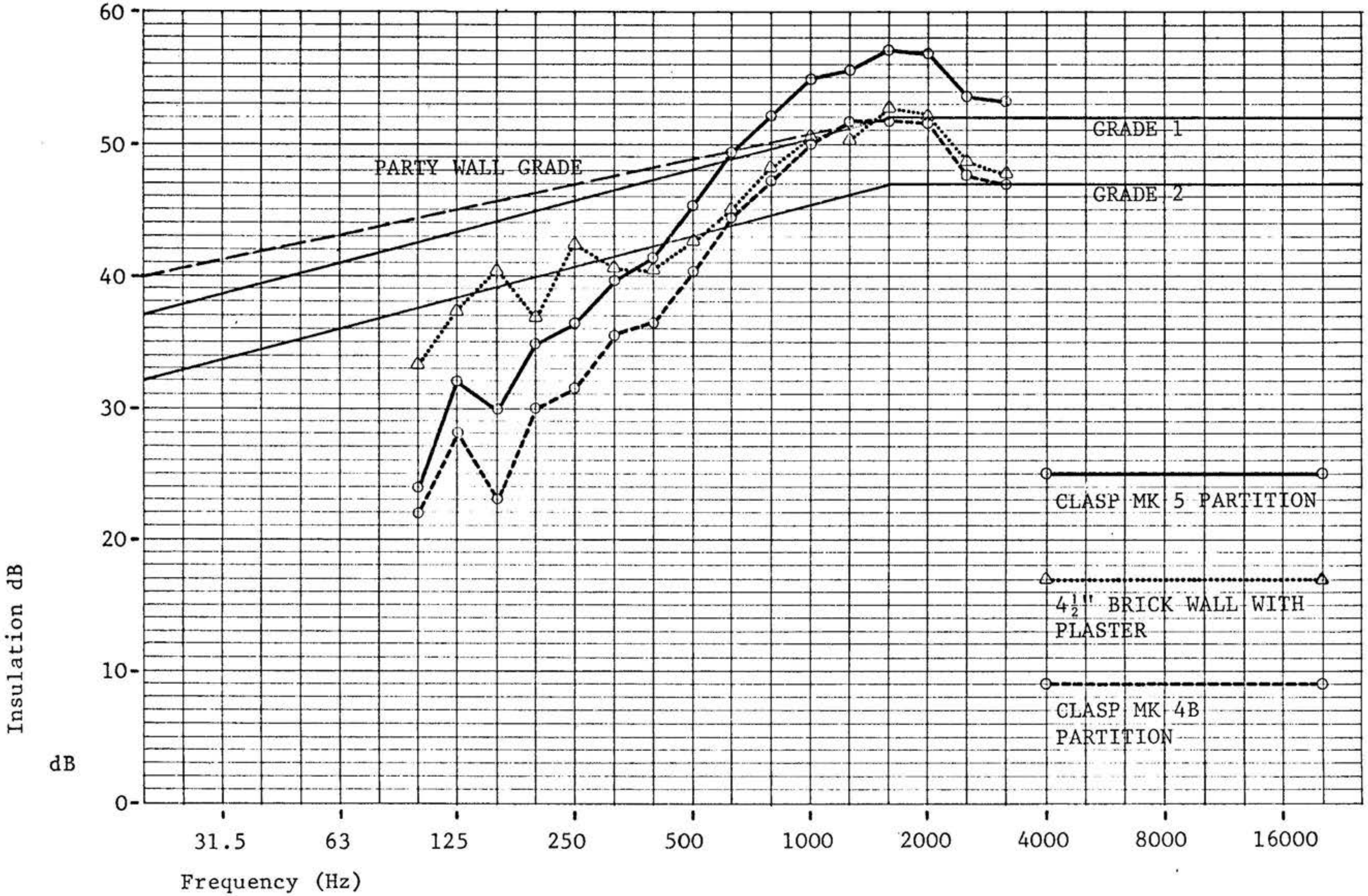


FIG 5.1 THE PERFORMANCE OF THE CLASP PARTITIONS IN RELATION TO TRADITIONAL CONSTRUCTION AND THE BRITISH GRADING SYSTEM.

than the maximum deviation of 23 dB which is permissible under this particular grading process. It should also be noted that this conclusion is applicable to a partition erected to laboratory standards of workmanship.

In Fig 5.1 the results of tests on a typical 4½" brick and plaster partition at the Woodside health centre, are also compared with CLASP sub-group A2, A3 and A6. This shows the superior performance of the brick partition at frequencies below 600 Hz, achieving Grade II standard with a minimum adverse deviation of 13 dB.

Finally, the same diagram also illustrates the potential development from Mk 4B to Mk 5 level of performance, assuming that careful attention is given to sealing at all junctions especially in the region of the plenum barrier. The average difference in sound insulation for these two graphs is 4.6 dB.

The British standard grading curves do not adequately describe the performance of partitions in buildings other than dwellings, particularly if speech privacy is the primary concern. An alternative method of rating is contained in ISO R717 [69] which although still aimed at dwellings, places more emphasis upon the sound insulation performance at higher frequencies. The standard reference curve used in this procedure is shown in Fig 5.2 and may be taken as a fixed reference, in which case, it is directly comparable with the British Grade 1 curve for dwellings; alternatively, it can be displaced in steps of 1 dB towards the measured curve until the most severe of the following conditions is satisfied :-

a) the mean unfavourable deviation, computed by dividing the sum of the unfavourable deviations by the total

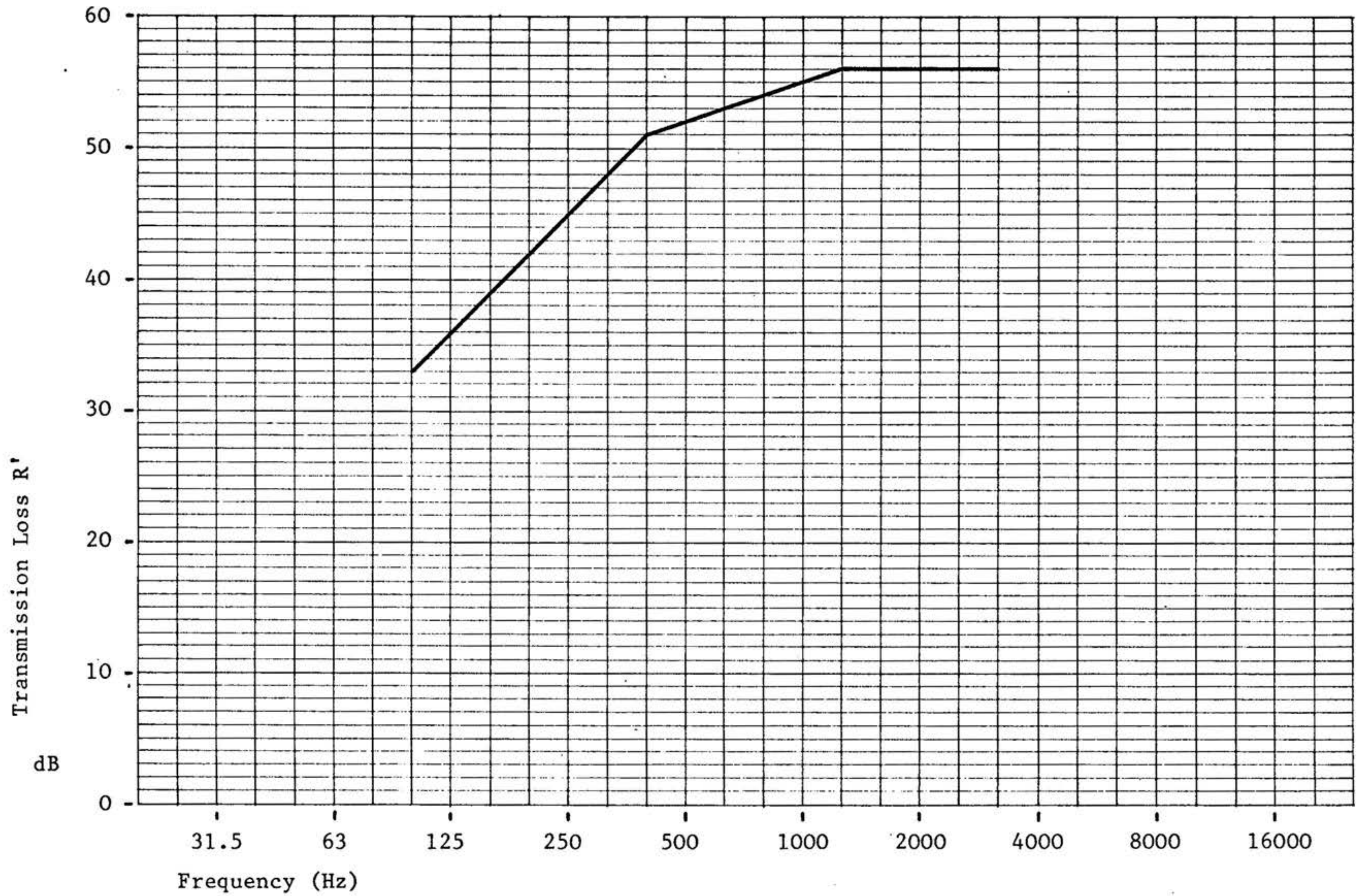


FIG 5.2 STANDARD REFERENCE CURVE USED IN ISO R717 GRADING PROCEDURE.

number of measuring frequencies, is greater than +1 dB but not more than 2 dB

or, b) the mean unfavourable deviation is less than 2 dB and the maximum unfavourable deviation at any frequency does not exceed 8 dB for measurements in 1/3 octave bands or 5 dB for measurements in octave bands.

The amount by which the reference curve has to be displaced to meet this overall requirement is then deducted from a constant of 52 dB and the resulting single number index (specifically referred to as the Insulation Index, Ia) may then be used to describe the degree of speech privacy provided by that partition. Identical STC (Sound Transmission Class) values are yielded by a similar procedure[70]. Either of these indices appear to correlate well with the results of the laboratory experiments.

The values of the Insulation Index (or STC classification) for each of the partitions tested are listed in table 5.1. It may be noted that the CLASP Mk 5 partition of test B2 has an identical rating with the 4½" brick partition although the former failed to achieve Class II rating under the British system.

5.3 Allowance for flanking transmission.

Under standard laboratory procedures flanking paths are excluded, the only significant variables being the fixing, workmanship and size of the specimen, coupled with the effect of absorption in the receiving room. Size of partition and absorption in the receiving room are normalized using the formula $10 \log_{10} \frac{S}{A}$ where S is the area and A the total absorption, the result being designated the Sound Reduction Index (R). Variations between laboratory and field measurements may therefore be attributed to different conditions of edge fixing; to minute air gaps; to

Test nos	Average Sound Insulation (R')	Insulation Index (Ia) or STC Classification	Difference R'/Ia
A1-7 inclusive	37.6	41	3.4
A1, 4 & 5	36.7	39	2.3
A2, 3 & 6	39.7	43	3.3
A7 & 8	35.4	39	3.6
B1	37.9	40	2.1
B2	44.3	47	2.7
B3	25.3	26	0.7
B4	29.9	32	2.1
B5	38.6	43	4.4
B6	32.2	34	1.8
B7	35.1	38	2.9
C1	25.5	29	3.5
C3	37.0	41	4.0
C4(a)	28.9	32	3.1
C4(b)	31.1	35	3.9
C5	29.7	34	4.3

TABLE 5.1 RATING OF AIRBORNE SOUND INSULATION.

flanking walls which exist in the field location but not in the laboratory; or to a combination of two or more of these factors. Usually therefore the Airborne Sound Insulation (R'), Insulation Index (Ia), or the Normalized Level Difference (any of which may be used to describe field results) yields a lower value than the Sound Reduction Index.[71]

This is illustrated in Figs 5.3 and 5.4. In the first of these the average of all field tests (series A) is compared with laboratory tests on a similar partition. The variations above 1000 Hz are almost certainly due to the presence of small air gaps. It is more difficult to account for the variations below 800 Hz, which may be due to bending wave transmission or a similar mechanism, in the flanking walls. In Fig 5.4 there is no evidence of the latter, although the effect of air gaps is also apparent. Graphs showing the field performance both with and without plenum barriers are presented in this figure, in addition to the laboratory results.

Insulation indices (Ia) determined in accordance with ISO R717 for the two conditions shown in Fig 5.3 are 47 and 41, giving a difference of 6 dB in ratings. In Fig 5.4 the ratings for the laboratory specimen and the lower of the two field locations are 43 and 39 respectively, the difference being 4 dB.

An allowance of -4 to -6 dB must therefore be made in using the laboratory determined Sound Reduction Index as a base from which to predict the Insulation Index which relates to field conditions, and further adjustments must be made if the surface area of the partition varies appreciably from 10 sq. metres and the reverberation time in the receiving room from 0.5 seconds.

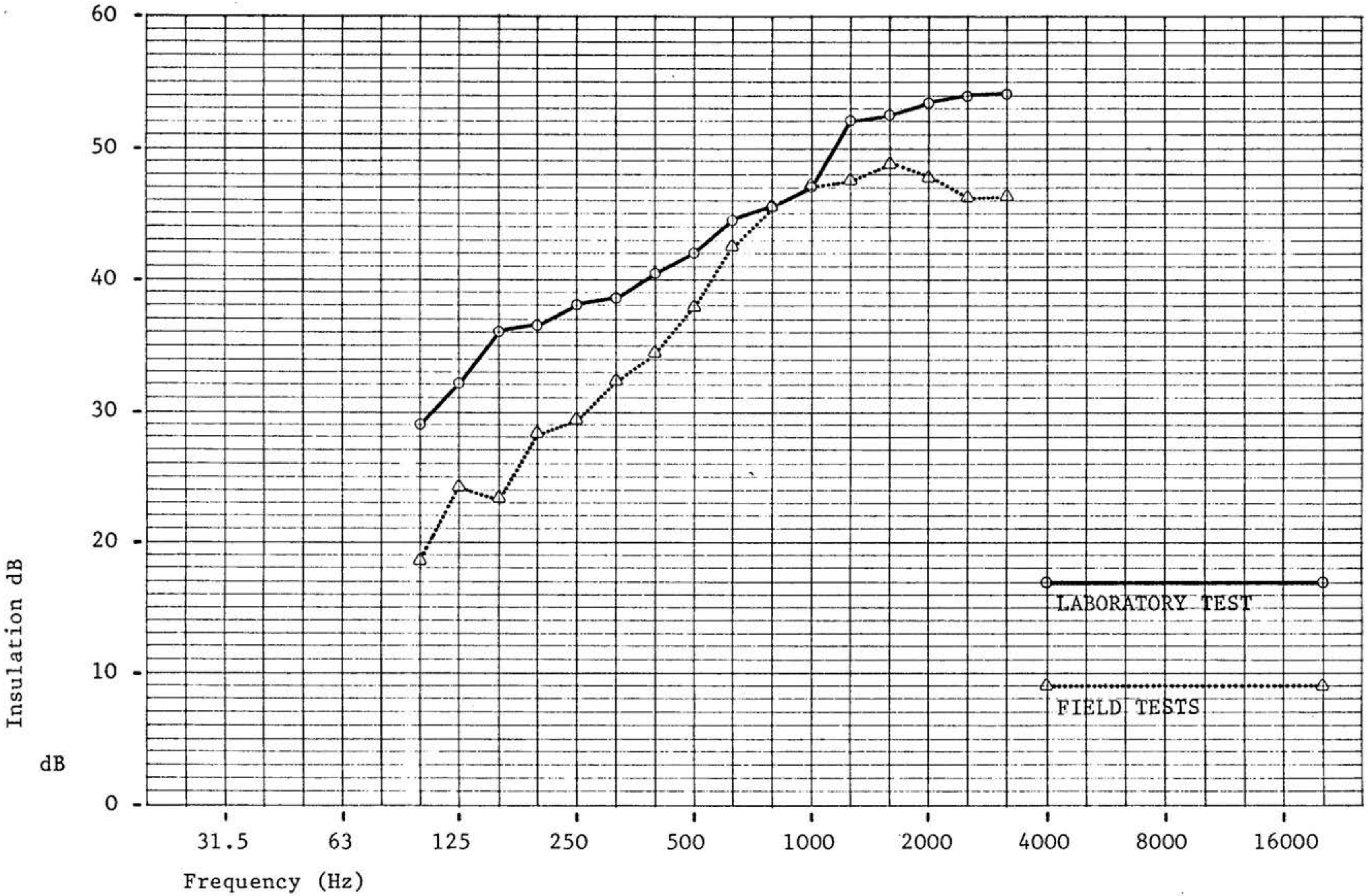


FIG 5.3 COMPARISON OF MEANS (RESULTS FROM FIELD AND LABORATORY TESTS) - CLASP MK 4B PARTITION.

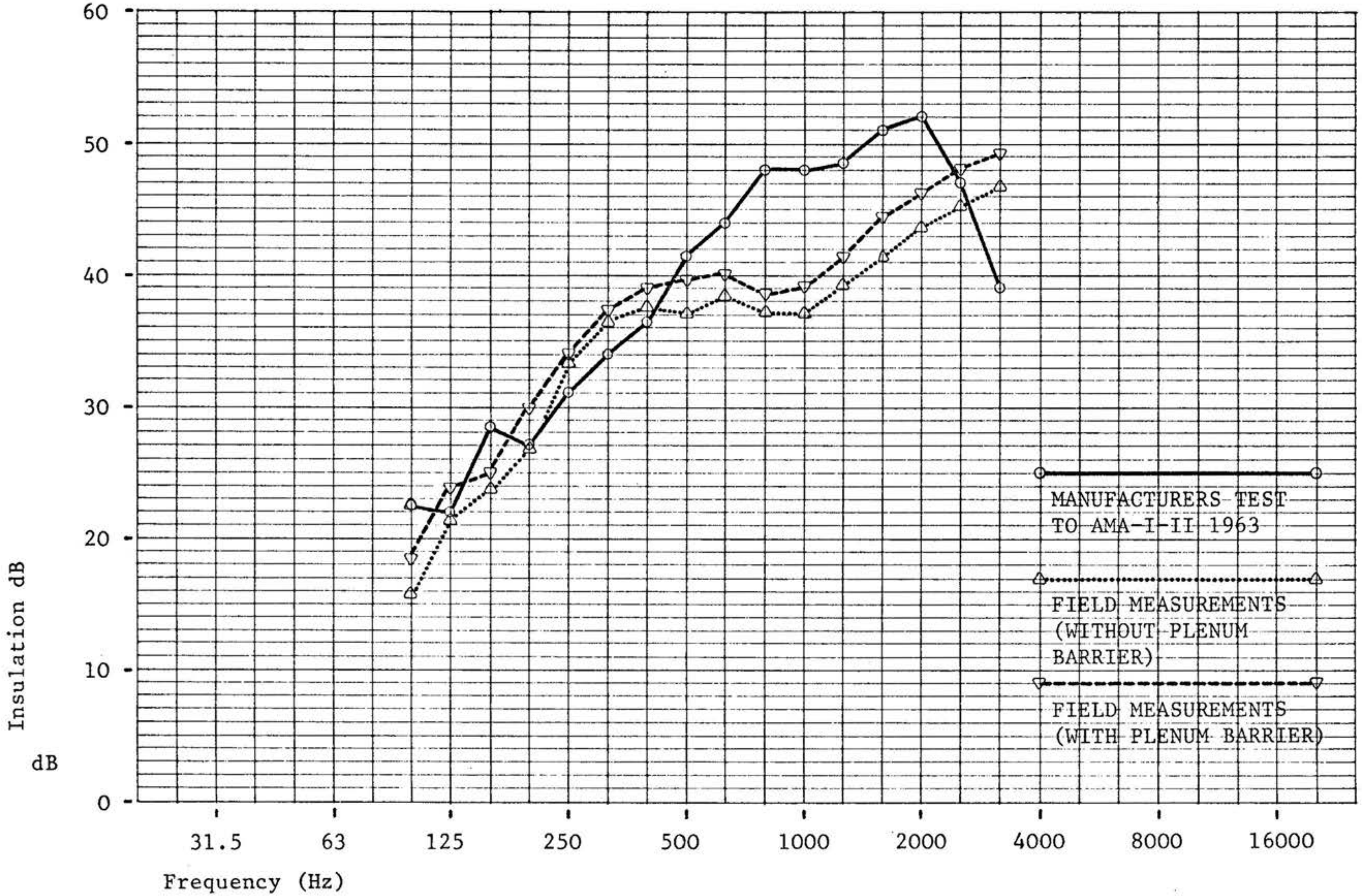


FIG 5.4 COMPARISON OF FIELD AND LABORATORY RESULTS - STANDARD PLASTERBOARD PARTITION.

5.4 Absorption characteristics of the receiving room.

The effective sound insulation is dependent not only upon the partition and associated transmission paths but also upon the area of the partition in relation to the total absorption present in the receiving room. There are three main formulae which are in use both to normalize laboratory data and to account for differences in receiving room characteristics. The following abbreviations are used throughout :- T, measured reverberation time; A, total absorption in the receiving room; S, surface area of partition; F, floor area; V, room volume.

The first formula $10 \log \frac{A}{10 m^2}$ is listed in B.S. 2750:1956, specifically for use in relation to dwellings.

The second formula $10 \log \frac{T}{0.5 \text{ sec}}$ is also listed in the same document, and has been widely adopted in Britain.

A third form ($10 \log \frac{S}{A}$) was originally introduced to normalize laboratory results and its use has been subsequently extended for field use (in the first case it is designated as the Sound Reduction Index (R) and the second as the Airborne Sound Insulation (R')).

The third formula (formally proposed in ISO R717) yielded the best fit for the initial series of measurements on CLASP 4B partitions and has been used throughout in stating the results of field measurements.

The results of reverberation time measurements for all test series are illustrated in Figs 5.5- 5.9 and the total absorption has been

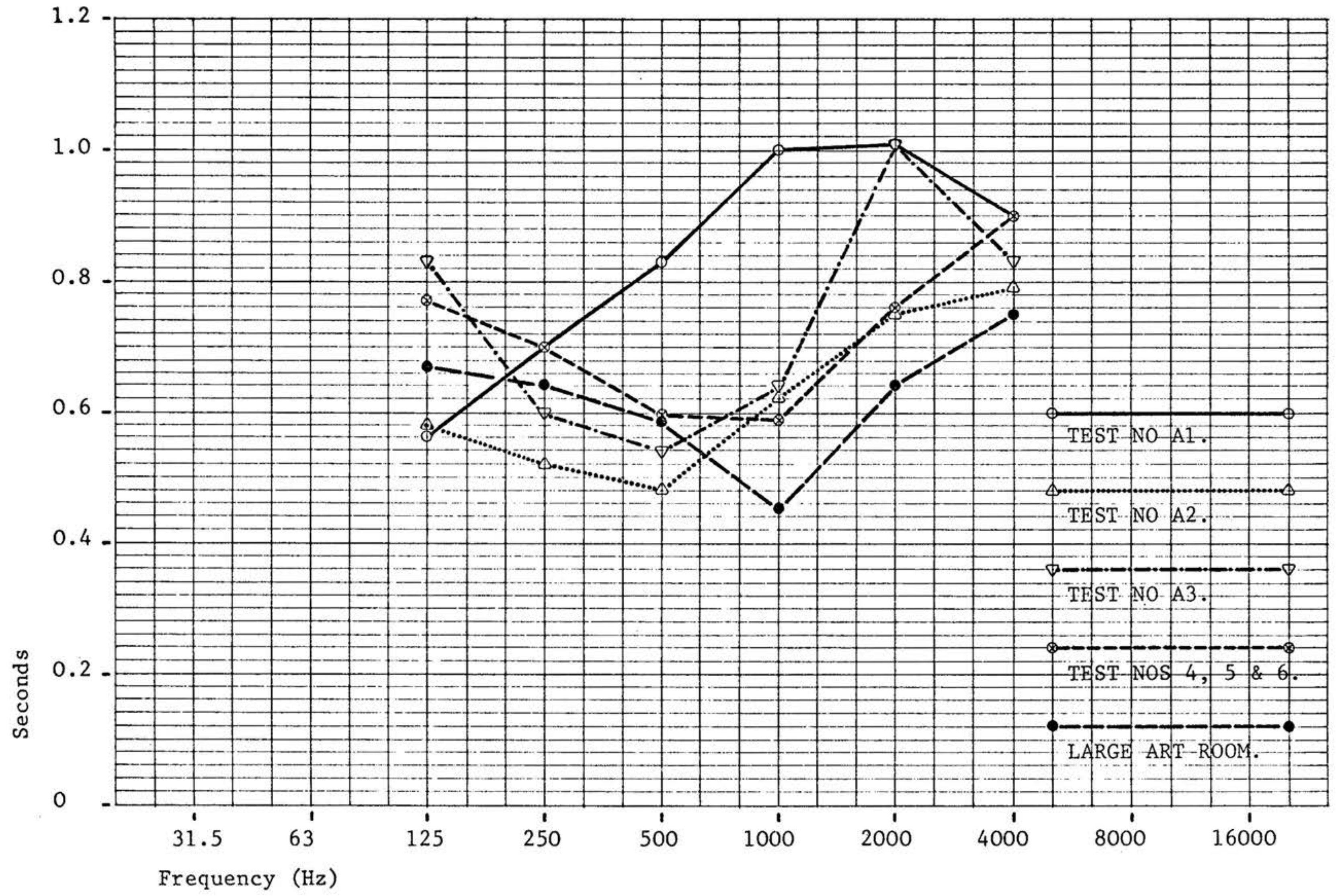


FIG 5.5 REVERBERATION CHARACTERISTICS OF VARIOUS ROOMS USED FOR TESTS A 1-6; IN EAST LOTHIAN SCHOOLS (OCTAVE BAND MEASUREMENTS).

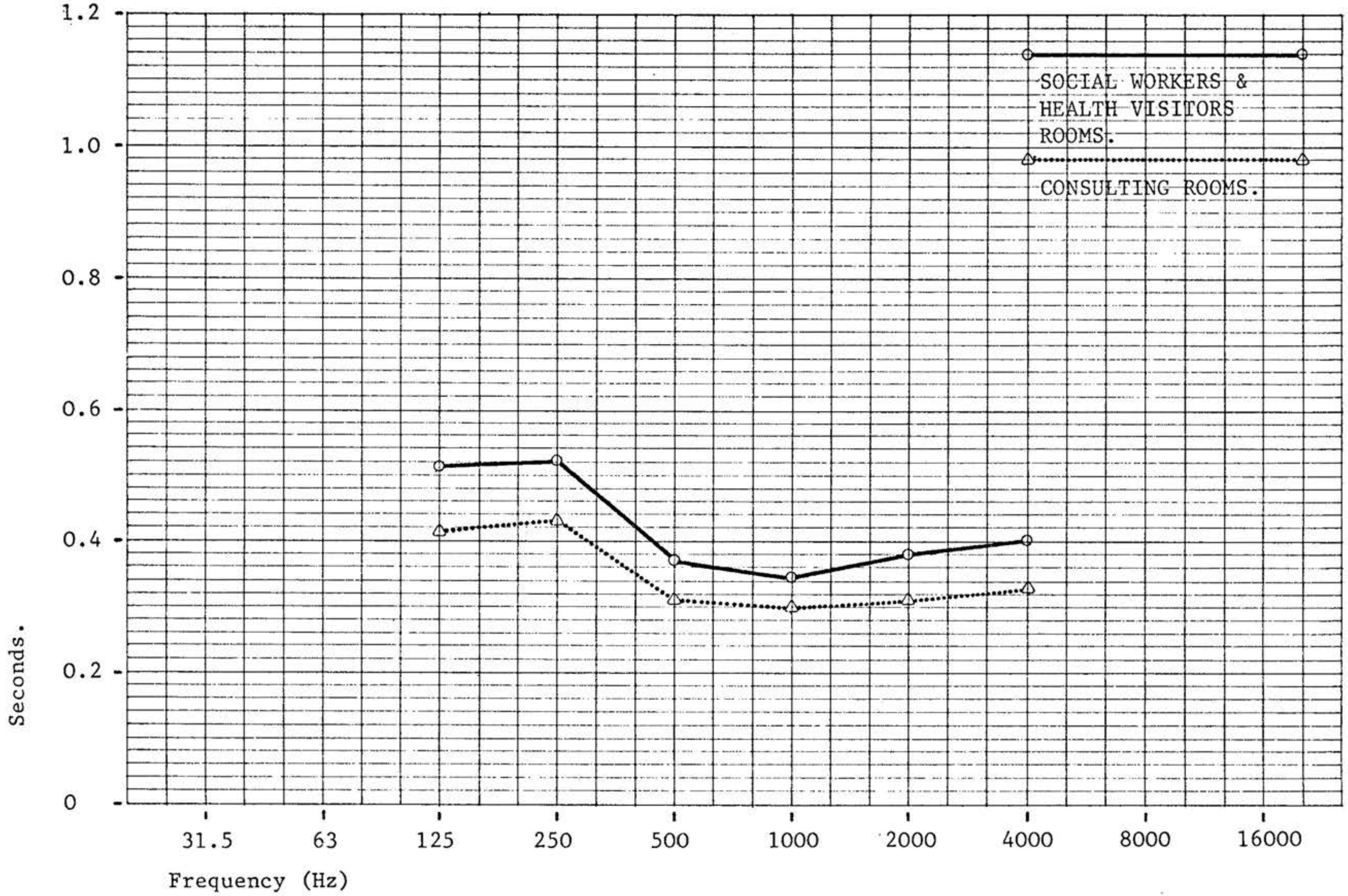


FIG 5.6 REVERBERATION CHARACTERISTICS OF VARIOUS ROOMS USED FOR TESTS A 7 AND 8; IN THE DUMBARTON HEALTH CENTRE (OCTAVE BAND MEASUREMENTS).

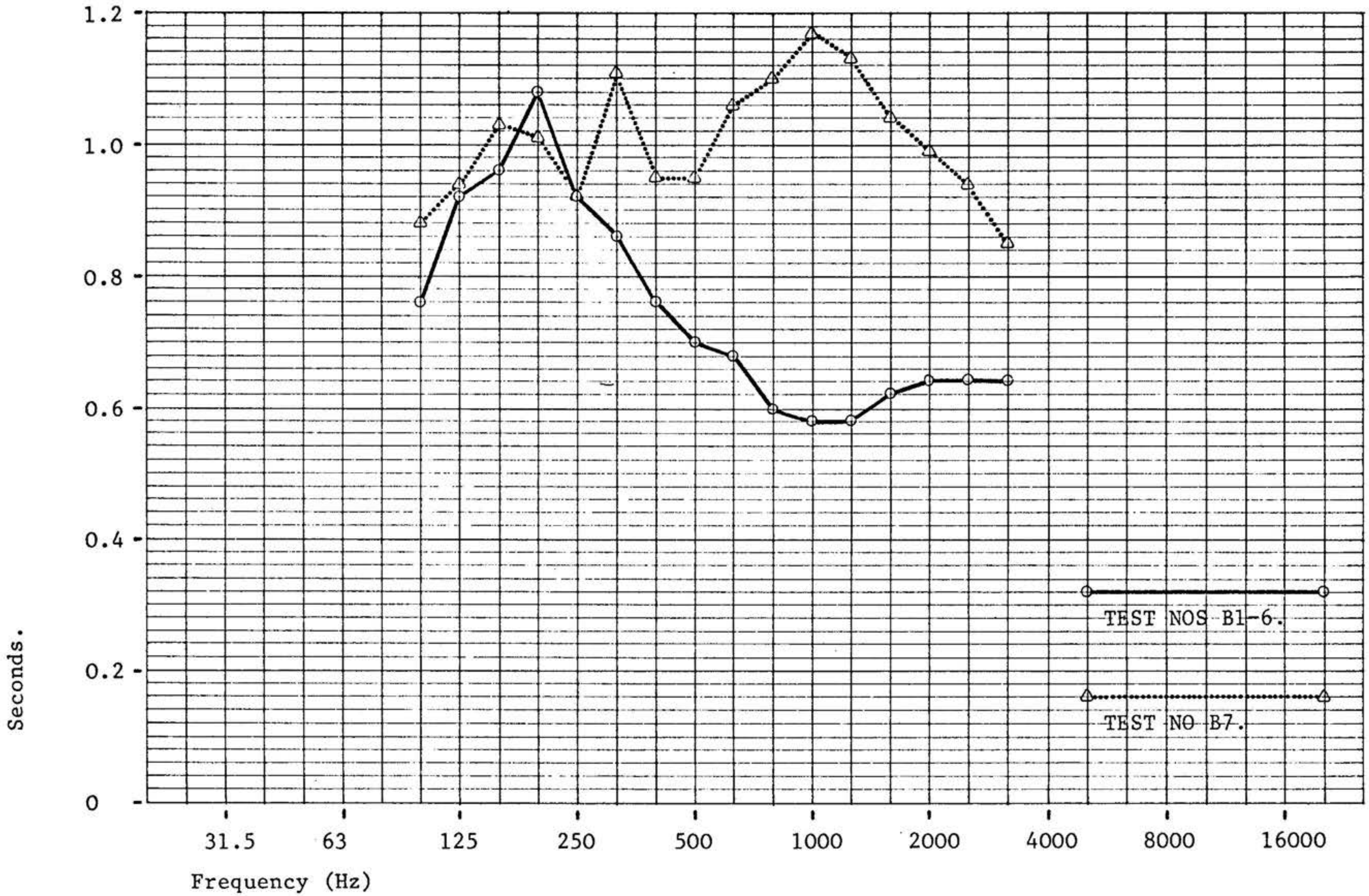


FIG 5.7 REVERBERATION CHARACTERISTICS OF THE CLASP MK 5 PROTOTYPE AT PAISLEY (1/3 OCTAVE BAND MEASUREMENTS).

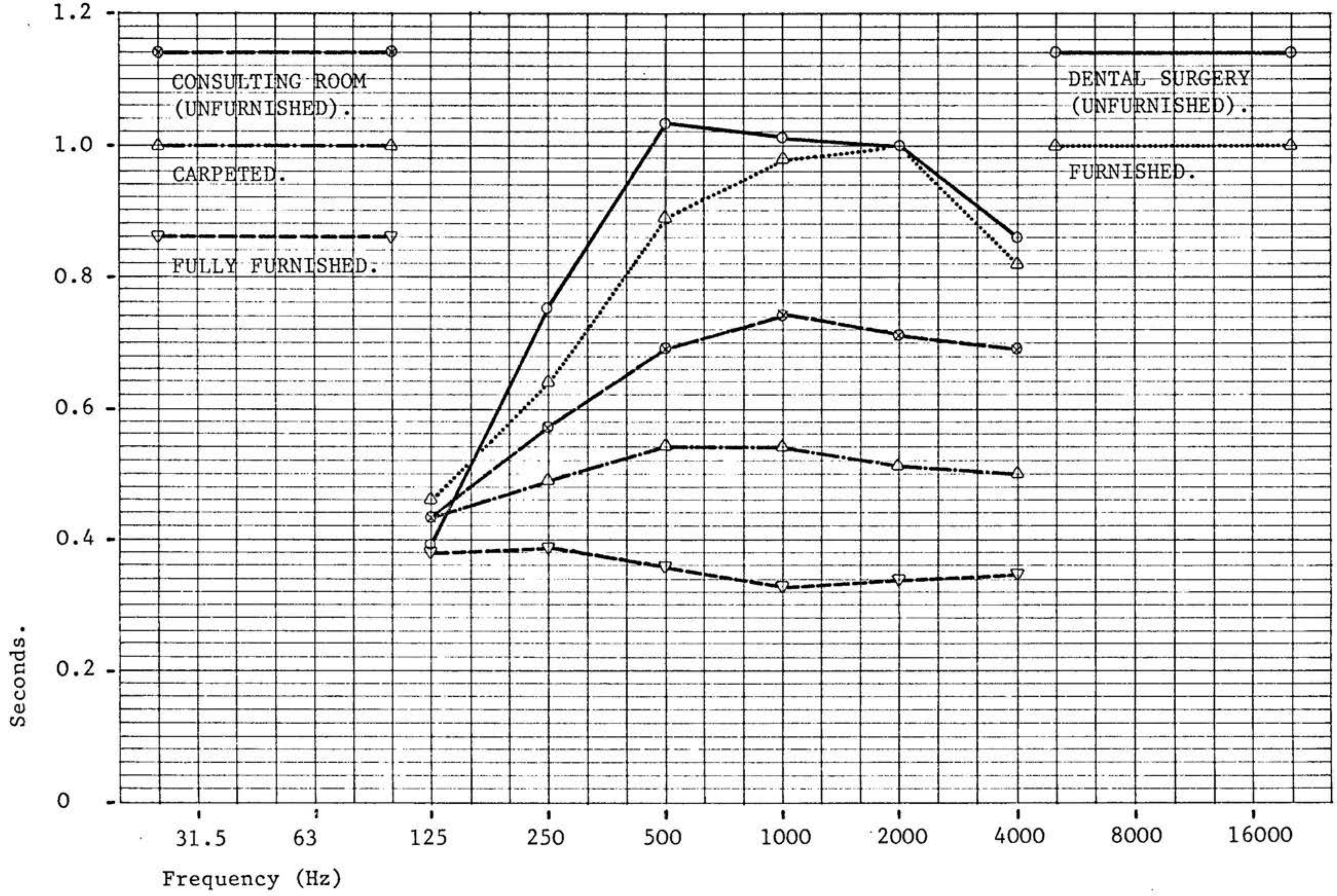


FIG 5.8 REVERBERATION CHARACTERISTICS OF DENTAL SURGERIES AND CONSULTING ROOMS IN THE OUTPATIENTS' DEPARTMENT OF FALKIRK ROYAL INFIRMARY(OCTAVE BAND MEASUREMENTS).

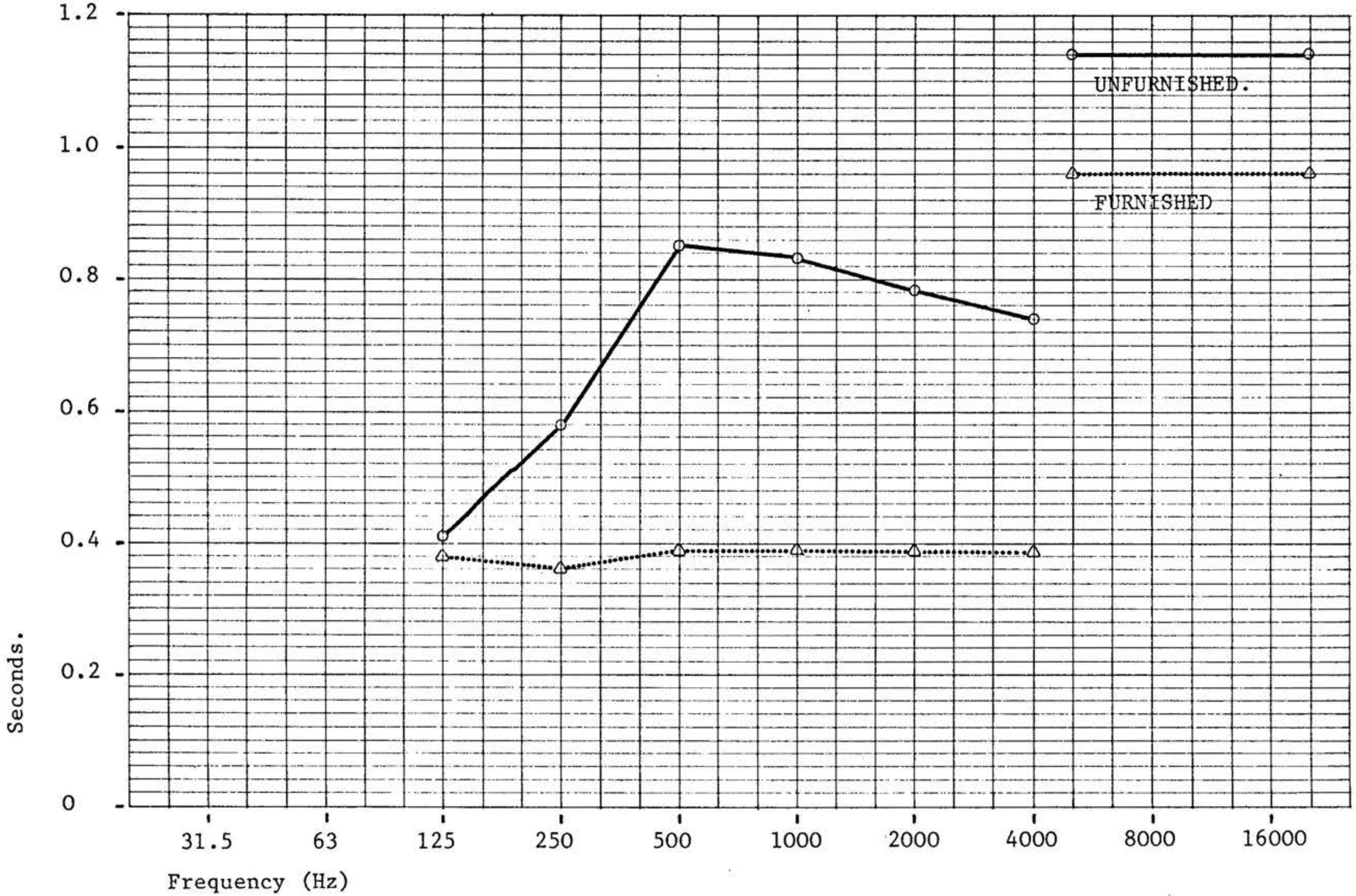


FIG 5.9 REVERBERATION CHARACTERISTICS OF A SMALL DENTAL OFFICE (OCTAVE BAND MEASUREMENTS).

calculated using Sabine's formula $\frac{0.049 \times V}{A}$ (Imperial form)

or $\frac{0.16V}{A}$ (Metric form)[72].

All the relevant information relating to absorption characteristics is presented in tables 5.2 and 5.3.

A linear regression analysis of this data shows that for this test sample, A (total absorption) $\simeq$ 0.79F (floor area), the correlation (r) being 0.81. This relationship provides the basis for the graph shown in Fig 5.10. The graph may be used to obtain a correction factor for airborne sound insulation (R') if the area of both partition and receiving room are known.

	FIGURE AND CURVE NO.							
	25(1)	25(2)	25(3)	25(4)	26(1)	26(2)	27(1)	27(2)
	TEST NO.							
FREQ	A1	A2	A3	A4,5&6	A7	A8	B1-B6	B7
100	129	239	66	214	105	183	62	54
125	122	243	71	217	95	161	51	50
160	114	247	80	223	88	143	49	46
200	107	256	88	232	88	140	44	47
250	98	271	99	239	93	153	51	51
315	93	282	104	249	107	173	55	43
400	88	294	107	265	121	194	62	50
500	83	294	109	278	131	213	68	50
630	78	271	107	298	138	220	70	45
800	73	247	102	309	142	220	79	43
1000	69	228	92	283	144	220	82	40
1250	64	211	78	257	138	220	82	42
1600	62	199	66	235	134	220	76	46
2000	62	188	57	220	127	213	74	48
2500	65	183	60	206	121	206	74	50
3150	69	181	64	194	121	206	74	56
Average (ft / sabins)	86	240	84	245	118	193	66	48
Floor area (F) (ft)	143	291	124	341	123	168	124	124
Room vol (V) (ft)	1400	2880	1205	3408	3408	3408	966	966

TABLE 5.2 ABSORPTION CHARACTERISTICS OF RECEIVING ROOMS. (TEST SERIES A AND B).

	FIGURE AND CURVE NO							
	28(1)	28(2)	28(3)	28(4)	28(5)	28(6)	29(1)	29(2)
	TEST NO							
FREQ	C2&C3	C2&C3	C1	C4	C5	-	C2&C3	-
100	163	174	163	179	193	198	115	121
125	170	159	170	170	193	193	118	127
160	153	144	153	163	193	193	110	134
200	141	131	141	156	188	188	96	134
250	129	115	129	150	188	188	83	134
315	118	100	118	144	193	188	74	130
400	111	88	111	138	198	183	63	127
500	106	82	106	136	204	183	57	124
630	102	78	102	133	209	188	55	124
800	99	76	99	133	216	188	56	124
1000	99	75	99	136	222	188	58	124
1250	99	73	99	138	222	183	60	124
1600	102	73	102	141	216	183	60	124
2000	103	73	103	144	216	179	62	124
2500	105	76	105	144	216	175	63	124
3150	105	81	105	147	209	175	65	127
Average (ft^2 / sabins)	119	100	119	147	205	186	75	126
Floor area (F) (ft^2)	187	187	187	187	187	187	123	123
Room vol (V) (ft^3)	1496	1496	1496	1496	1496	1496	984	984

TABLE 5.3 ABSORPTION CHARACTERISTICS OF RECEIVING ROOMS. (TEST SERIES C).

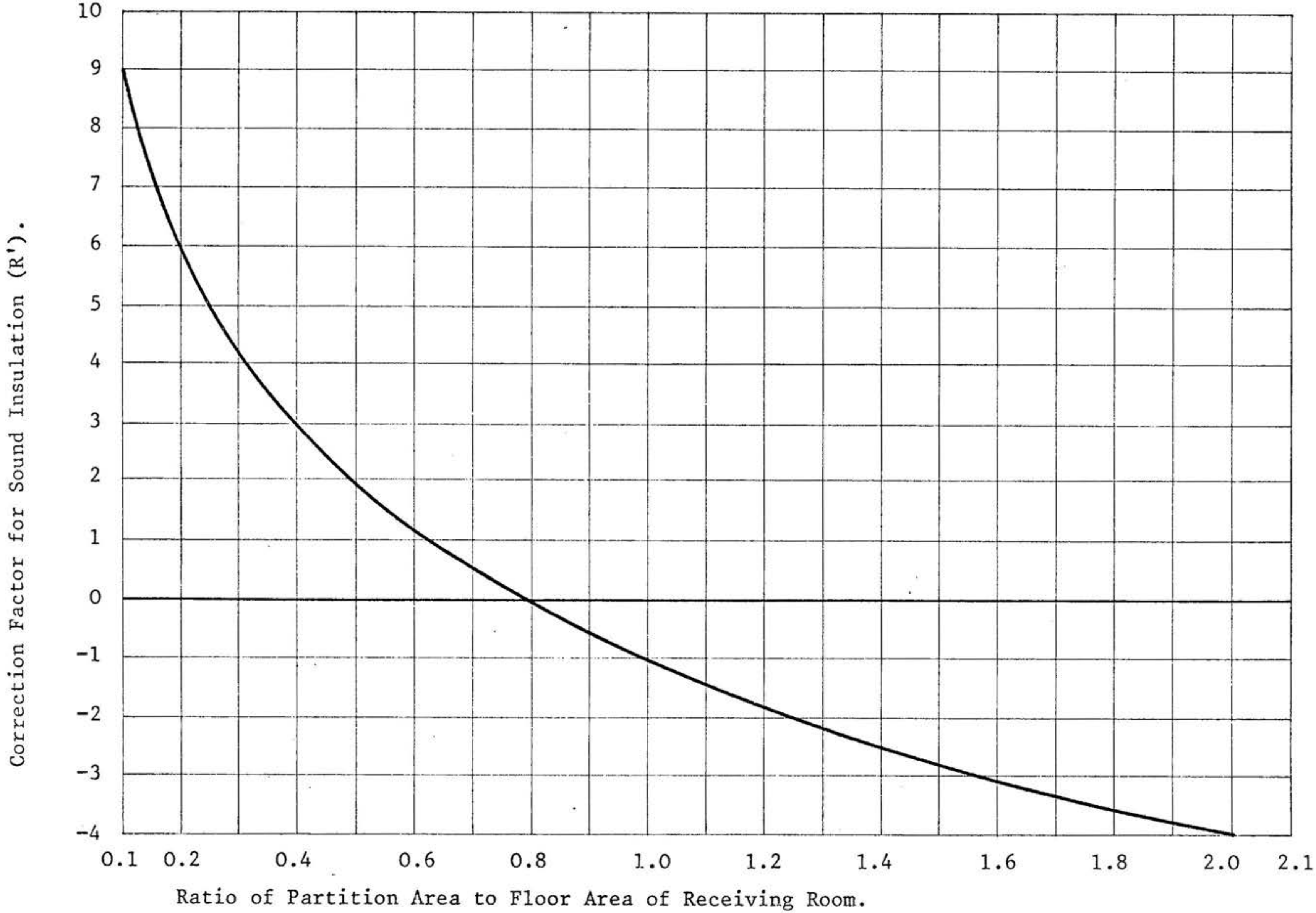


FIG 5.10 CORRECTION FACTOR TO BE ADDED TO AIRBORNE SOUND INSULATION (R') OF PARTITION, ALLOWING FOR AREA OF PARTITION IN RELATION TO AREA OF RECEIVING ROOM.

CHAPTER VI PART A. PREDICTION OF SPEECH PRIVACY.

6.1 General.

This chapter is written primarily for use by job architects. It is in effect a summary of all the experimental findings of previous chapters, integrated and expressed so that a detailed knowledge of acoustic terminology or mathematics is not required of the reader.

It is possible to draw general conclusions about the degree of privacy provided in various circumstances by direct reference to the graphs of Figs 2.6, 2.7, 2.10 and 2.12 using the Airborne Sound Insulation (R'). These conclusions will only be approximate and valid when certain conditions apply, i.e. the reverberation time of the consulting room is approximately 0.4 seconds and the partition area is approximately 10 square metres. When these conditions are not met then adjustments must be made if an accurate prediction is to follow.

The following predictive method is drawn up in the form of a check list with associated arithmetical calculations which allows for these variations. The designer who works through this system should become thoroughly acquainted with the relative importance of the various acoustic factors under his control. Certain standard procedures relating to measurement, etc. are assumed as part of the predictive method - for anyone who is not fully conversant with these ancillary procedures, footnotes and additional data are included in Chapter VI Part B. (The annotation of Part B is synonymous with that of Part A.)

6.2 A method for predicting degree of speech privacy and reaction of occupants.

A detailed plan of the proposed building should be examined to determine the exact number of partitions and associated sets of conditions which will require individual analysis by this method. It should also be noted that the sequence varies depending whether the partition is between consulting rooms with identical ambient noise levels, or between a consulting room and a corridor or waiting area with different noise levels.

6.2.01 Building designation.

6.2.02 Partition number(s).

6.2.03 Occupancy classification.

6.2.04 Reference voice level rating.

(Average sound pressure level in dBA. For normal circumstances select +58 dB for health centres.)

Conversational level in consulting room.	+ 58
Raised voice	+ 63
Very loud, almost shouting.	+ 68

6.2.05 Hearing sensitivity rating of recipient, due to effect of age. (Under normal circumstances use zero rating for health centres.)

	Correction Factor.
Age 29 or less.	0
" 30 to 39	- 2
" 40 to 49	- 4
" 50 and over	- 7

6.2.06 Attitude rating of recipient. (Under normal circumstances use zero rating for health centres.)

	Correction Factor
Very critical, listening carefully in room with no other occupants.	0
Critical, but engaged in activity involving slight movement.	- 3
In conversation with another room occupant.	- 6

6.2.07 Allow for sound absorption provided by room furnishings in the receiving room (see specifications in note 6.2.07B).

	Correction Factor
Above average	- 3
Average	0
Minimal	+ 3

6.2.08 Sound insulation data for partition. (Use normalized level difference if available.)

- $\boxed{}$

6.2.09 <u>Allow for the shape of the sound insulation spectrum</u> (see following table).

	Correction Factor
Class A - slope 0-4dB/octave or X	0
Class B - slope 4-6dB/octave	- 3
Class C - slope 6dB/octave	- 6

6.2.10 <u>Additional allowance for flanking transmission</u> if not already accounted for in 6.2.08. (This will only be required if laboratory data is in the form of the sound reduction index if used in 6.2.08)

6.2.11 <u>Allow for variation in the ratio of partition area/floor area of receiving room.</u>

Ratio of partition area : floor area.	Correction Factor.
1 : 1.9	- 1.0
1 : 1.7	0
1 : 1.5	+ 1.0

6.2.12 <u>Determine the CORRECTED INTRUDING SPEECH LEVEL by summing the result of 6.2.04 to 6.2.11, carefully noting all signs, and retain the result for future reference.</u>

6.2.13 <u>If the receiving room is a consulting room, estimate or measure the basic EXTERNAL NOISE CLIMATE.</u>

The following table is based upon data provided by the London noise survey and will give a reasonable first approximation to the external ambient noise for most health centre sites.

If the proposed building is adjacent to a major road (e.g. a motorway or heavily used A class road) with a traffic flow exceeding 10,000 vehicles per 18 hour day (06.00 to 24.00 Monday to Friday) a more precise prediction of the exposure to noise may be made by reference to other publications.

SITE CATEGORY (Adjacent to or within)	Reference level L_{50} dBA
Arterial road with many heavy vehicles and buses.	74
A major road with heavy traffic <u>or</u> a side road within 15-20 metres of either arterial or major road.	69
A main residential road, a side road within 20-50 metres of heavy traffic routes <u>or</u> within a courtyard screened from direct view of heavy traffic.	65
A residential road with only local traffic.	60
A minor road, <u>or</u> a garden site with major traffic routes more than 100 metres distant.	55
A park, courtyard or garden in a residential area well away from traffic routes.	52
A place of few local noises and only very distant traffic noise.	48

6.2.14 <u>Allow for a reduction or an increase in the basic external noise climate due to shielding or reflection effects from the proposed building, existing adjacent buildings, earthworks and similar screens.</u>

6.2.15 Estimated sound reduction of consulting room window when closed.

6.2.16 Estimated sound reduction of solid portion of external wall.

6.2.17 Approximate ratio of window/solid wall.

6.2.18 <u>CALCULATED NETT INSULATION OF EXTERNAL WALL</u>. (Refer to Fig 6.3)

6.2.19 Calculate the AMBIENT LEVEL IN THE RECEIVING ROOM by summing the results of 6.2.13, 6.2.14 and 6.2.18. N.B. Steps 6.2.15, 6.2.16 and 6.2.17 are intermediate, leading to 6.2.18.)

<u>ALTERNATIVELY</u>, if the receiving room is a corridor or waiting area usually steps 6.2.13 to 6.2.18 may be omitted and the internal ambient noise is obtained from the following table. If in doubt as to which category to select use interpolated values.

LOCATION	L'_{50} dBA Reflective walls, floor and ceiling.	Absorptive floor reflective walls and ceiling.	Absorptive floor and ceiling reflective walls.
Adjacent to reception desk or similar area with frequent conversations and through movements.	55	52	49
General waiting areas in close proximity to reception desk.	49	46	43
Individual practice waiting areas adjacent to main corridors.	43	40	37
Very quiet waiting areas isolated from main corridors and loud external noise.	38	35	32

6.2.20 Plot the CORRECTED INTRUDING SPEECH LEVEL (refer back to 6.2.12) against the AMBIENT NOISE LEVEL (refer to 6.2.19) on Fig 6.1 or Fig 6.2, depending upon whether the partition is between consulting rooms or between a consulting room and corridor or waiting area.

If the point plotted lies above the limit of the speech privacy zone the various assumptions should be re-examined with a view to improving the degree of isolation.

Also shown on Figs 6.1 and 6.2 are tentative limits for a zone of tolerance based upon field studies.

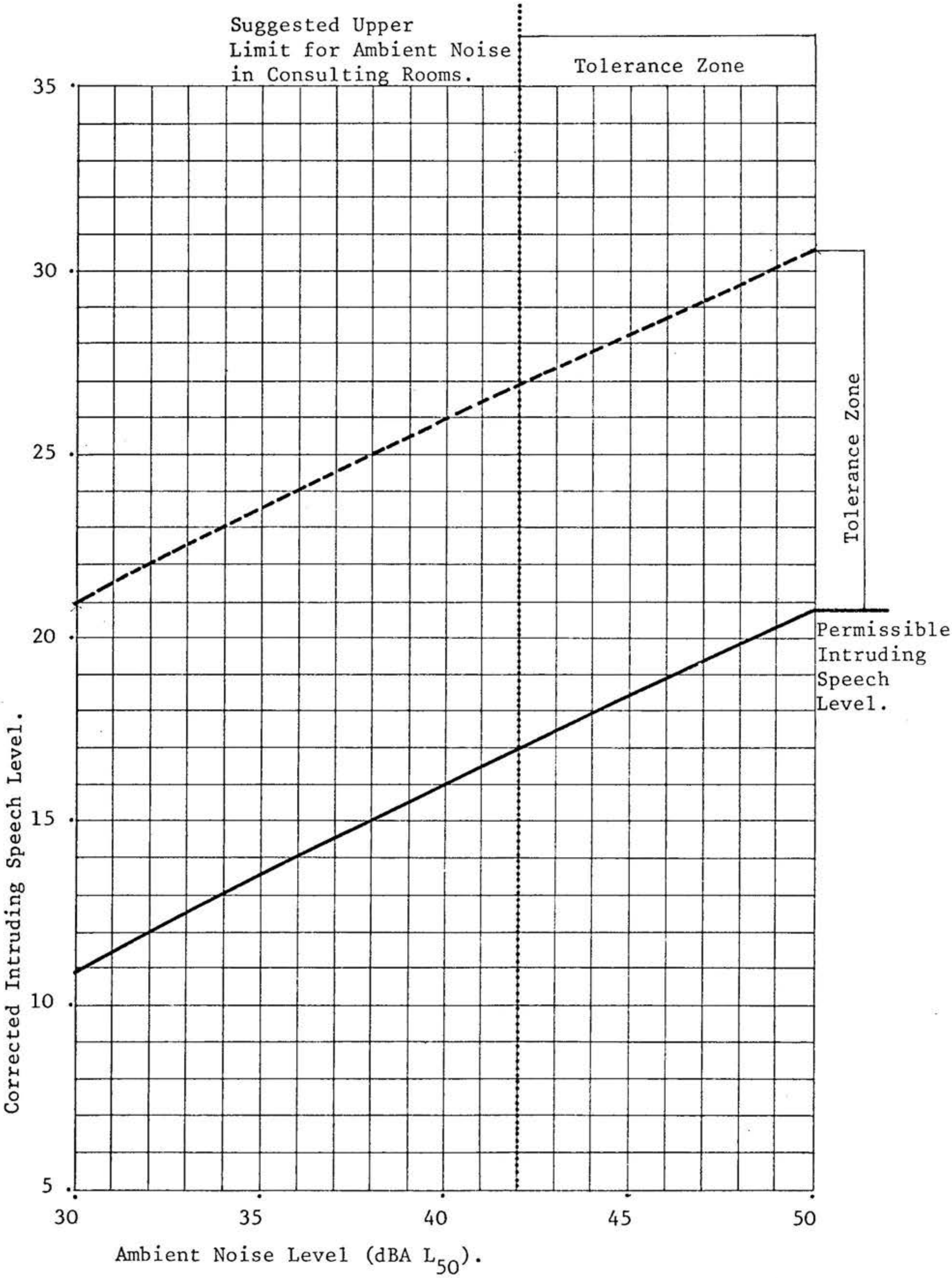


FIG 6.1 INTRUDING SPEECH AND AMBIENT NOISE LIMITS - PARTITION BETWEEN CONSULTING ROOMS WITH IDENTICAL NOISE CLIMATES.

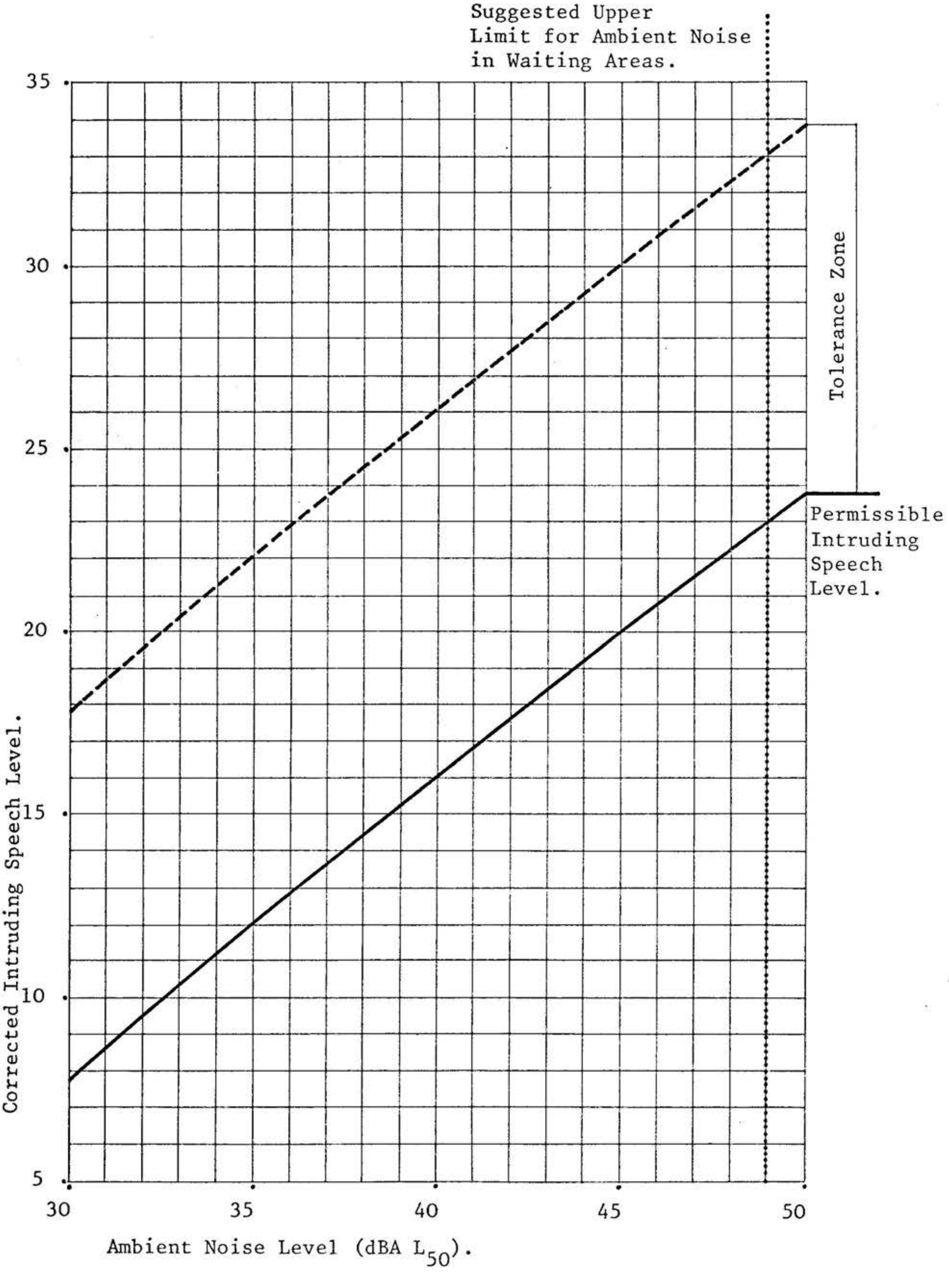


FIG 6.2 INTRUDING SPEECH AND AMBIENT NOISE LIMITS - PARTITION BETWEEN CONSULTING ROOM AND WAITING AREA (AMBIENT NOISE LEVEL IN CONSULTING ROOM TAKEN AT 40 dBA: LISTENER IN WAITING AREA ADJACENT TO CONSULTING ROOM ACCESS DOOR).

CHAPTER VI PART B ANCILLARY DATA AND EXPLANATORY NOTES TO SECTION VI A

N.B. The following notes are to be used in conjunction with the survey form of section VI A, therefore the sequence and notation are standardized.

6.2.01 If section VI A is required for correlation with a user response survey, each building will require a specific designation.

6.2.02 All partitions should be numbered on the key plan. Those which occur between identical room occupancies and ambient noise climates should be given the same designation.

6.2.03 If results following from Part A are to be correlated with a user response survey, room occupancies should be designated with reference to the following table:

Occupancy Group		Sex		Age Group			
				29 or less	30 to 39	40 to 49	50 and over
		F	M	1	2	3	4
Z	Doctor		✓			✓	
Y	Health Visitor						
X	Nurse						
W	Admin. Officer						
V	Receptionists						
U	Other Office Staff						

Thus a typical occupancy designation would read: Z/M/3

6.2.04 To simplify the calculations a constant reference voice level is used. The effect of variations of voice level in relation to ambient level is taken into account at a later stage.

6.2.05 The hearing sensitivity rating in this context refers only to physiological factors and will correlate with age on average. Wide variations within the same age group may still occur, however and these correction factors are only given as a guide to show why some occupants may tolerate lower insulation standards.

6.2.06 Attitude rating refers to psychological factors and may correlate with intelligence and introvert/extrovert ratings. As in 6.2.05 these factors are only a guide to the limit of the zone of tolerance.

The term "critical" refers specifically to the most sensitive 10% of all recipients who will tend to be more aware of a loss of speech privacy and are assumed to be in an attentive state.

6.2.07 Typical specifications for overall sound absorption are:

ABOVE AVERAGE.	Highly absorbent ceiling or wall approximately equivalent in area. Other fittings and fixtures as average.
AVERAGE.	Reflective walls and ceiling e.g. plaster or plasterboard, floor fitted with carpet, and a small additional amount of absorbent in the form of curtains and/or upholstered chairs.
Minimal	Hard floor covering, reflective walls and ceiling, e.g. thermoplastic tile floor, plaster on brick walls, plasterboard ceiling.

6.2.08 Sound reduction data to be taken from the British Standards Code of Practice CP3 Chapter III Part 2:1972. If relevant data is not available in this publication refer to The Airborne Sound Insulation of Partitions by E.N. Bazley, National Physical Laboratory, published by H.M.S.O. in 1966 or a textbook on building acoustics.

N.B. In an evaluation system of this kind it is essential to establish whether the Sound Level Difference, the Normalized Level Difference or the Sound Reduction Index is being quoted.

If the partition is composite i.e., it incorporates two areas of dissimilar construction, the overall sound insulation can be determined by using Fig 6.3.

The following table may also be used as a guide when a door is incorporated. It is assumed that the door is approximately 1/6th of the total area of the partition. (Use interpolated values if necessary.) The letters indicate insulation spectrum slope characteristics.

	Average Insulation Value of Partition					
	25 A	30 A	35 B	40 B	45 C	50 C
DOOR CONSTRUCTION						
Any door with air gaps at jambs and threshold.	21 X	22 X	23 X	23 X	23 X	23 X
Light door with single edge seals. (weight approx 5kg/m^2 spec. 1)	23 A	25 A	26 A	27 A	27 A	27 B
Heavy door with single edge seals. (weight approx 25kg/m^2 spec.2)	24 A	26 A	28 A	29 A	30 B	30 B
Very heavy door with double edge seals. (weight approx 50kg/m^2 spec. 3)	25 A	30 A	32 A	33 B	34 B	35 B
Heavy double doors with approx 8" space between. Single seals to each door.	25 A	30 A	35 B	39 B	41 B	42 B

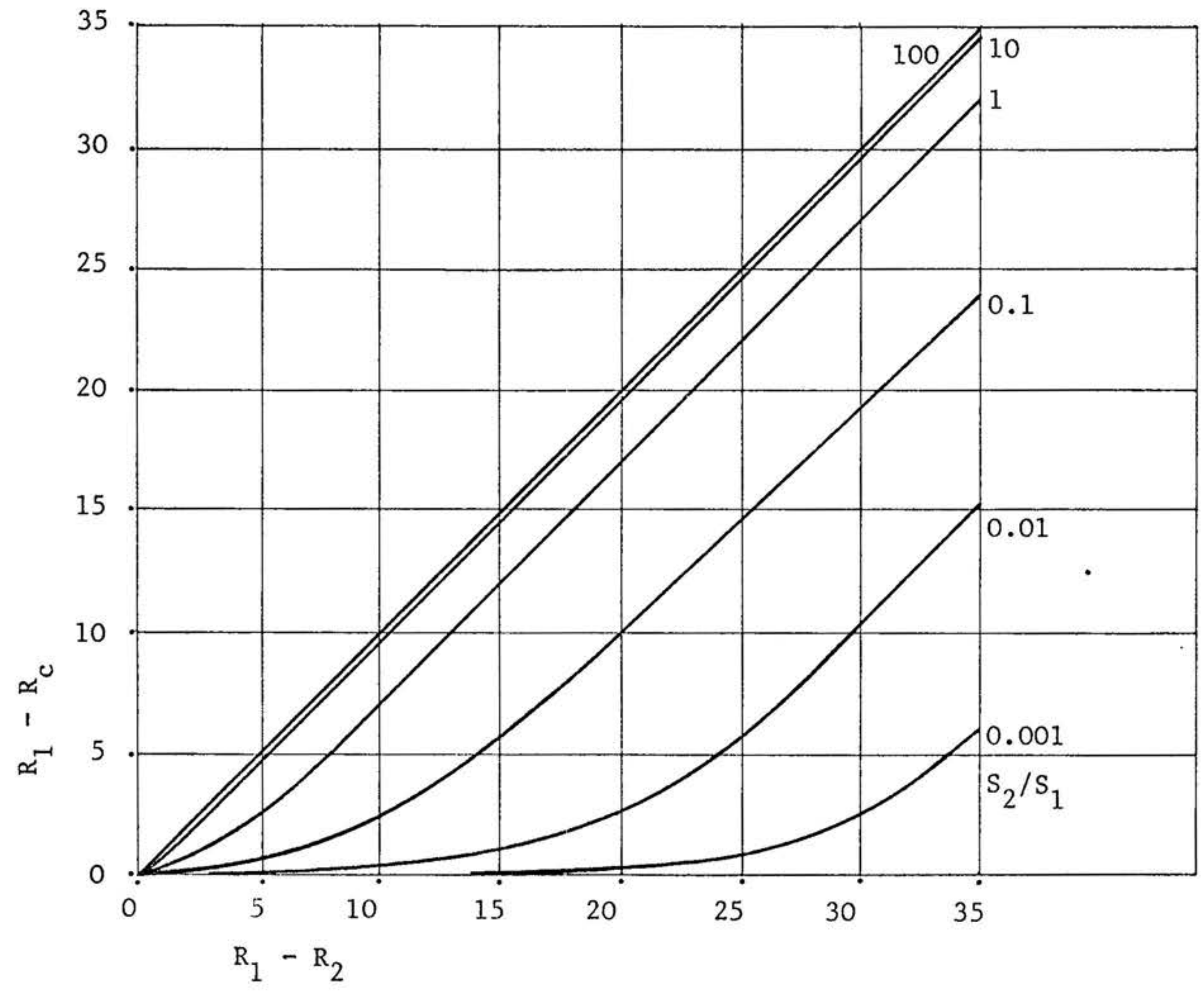


FIG 6.3 AIRBORNE SOUND INSULATION OF A TWO ELEMENT COMPOSITE PARTITION AS A FUNCTION OF THE RELATIVE INSULATION OF THE COMPONENTS. R_1 is the larger insulation value, R_2 is the smaller insulation value and R_c is the insulation value of the composite. S_2/S_1 is the ratio of the areas of the respective components. (Diagram due to I.L. Ver and C.I. Holmer.)

DOOR SPECIFICATIONS

1. 6mm plywood or hardboard faced skeleton core door.

2. Solid core flush door giving ½ hour fire resistance.

3. Asbestos cored door giving 1 hour fire resistance.

6.2.09 As stated in Chapter II, the degree of speech privacy provided by a partition will depend not only upon the average insulation over the frequency range 100 - 3200 Hertz, but also upon the slope of the sound insulation spectrum when plotted in 1/3 or 1/1 octave bands over that frequency range.

The insulation value may therefore be utilized in two alternate ways.

a. The average value in decibels over the agreed frequency range (100 - 3150 Hz) is taken together with a correction factor to account for the approximate slope of the insulation.

or, b. The insulation spectrum is graded in relation to previously agreed reference curves.

Method a. is used in BS CP3 Ch III, a letter being attached to describe the approximate slope characteristics.

Thus A (low) refers to a slope of less than 4 dB per octave.
B (average) refers to a slope of 4 to 6 dB per octave.
C (steep) refers to a slope of more than 6 dB per octave.

In this predictive method, X is also used to describe a flat slope, i.e. 0 dB per octave. Specifically, X is the lower limit of the A category and was taken as the reference line in the laboratory experiments.

Method b. If data is available graded in accordance with the ISO (International Standards Organisation) or the similar STC (Sound Transmission Class) procedures, this should be entered under 6.2.08 and no correction is required in 6.2.09.

6.2.10 If the sound insulation data used in 6.2.08 is based upon field measurements and is expressed as the normalized level difference in accordance with BS 2750:1956 it will not be necessary to make a further deduction for flanking transmission, provided that all wall and floor constructions are identical with those of the buildings from which the test results were obtained, and also provided that small openings and similar air gaps do not occur in the partition and adjacent elements.

<u>If laboratory data in the form of the sound reduction index is used, allowance for flanking transmission must be made.</u>

A detailed method of calculating flanking transmission is beyond the scope of these notes. The following simplified method may however be used as a guide:[73]

Step 1. Calculate the ratios of the superficial weights of flanking wall, roof and floor elements, to the superfiecial weight of the partition.

Step 2. Take equivalent loss factors for each flanking element from the following table:

Ratio of weight of flanking element to weight of partition.	Equivalent loss factor for one element.
4 or more	0
2 or more	3
1 or more	6
½ or less	8

Step 3. Add together the equivalent loss factors for all flanking elements and take the average. The result is the flanking transmission's correction factor to be deducted from the sound reduction.

N.B. In general it is assumed that partitions will be taken up to the underside of structural floors or roofs or, alternatively,that an infill bulkhead will be provided in all situations where the sound insulation is likely to exceed 30 dB.

6.2.11 The normalized level difference may require a further correction to allow for variation in the ratio of partition area/total absorption in the receiving room. The table given in 6.2.11 (A) utilizes the correction formula $10 \log_{10} \frac{S}{A}$ where S = total surface area of partition and A = total number of absorption units in the receiving room. The table is also based upon the assumption that in the room with an average amount of absorption, the total absorption is approximately proportional to floor area.

6.2.12 In carrying out the summation carefully, note all negative and positive signs. The resulting CORRECTED INTRUDING SPEECH LEVEL refers to the effective speech level which has penetrated to the adjacent room and is matched against the AMBIENT NOISE LEVEL at a later stage in the procedure.

6.2.13 Details of a suitable measurement procedure are given in Appendix V. Measurements should be verified by comparison with the table. When using the latter, if doubtful about the category, interpolate values.

More detailed methods of predicting the ambient noise are provided in the following publications and take into account the following factors:

a. The distance of the site from the road edge.
b. The nature of the ground traversed by the sound path.

c. The amount of noise reflected from surrounding surfaces.

d. The number of noise sources affecting the site.

1. Urban Design Bulletin, Traffic Noise - Major Urban Roads, Greater London Council, March 1970.

2. W.E. Scholes and J.W. Sargent, Designing Against Noise from Road Traffic, Building Research Station Current Paper 20/71. May 1971.

3. New Housing and Road Traffic Noise - A Design Guide for Architects. Department of the Environment Design Bulletin 26. H.M.S.O. 1972.

If followed in their entirety, the rules of these publications enable very detailed estimates to be made of L_{10} dBA noise levels on sites where the major sources are roads with traffic flows of the order stated. The L_{10} level must then be adjusted to obtain the L_{50} dBA masking level. The general relationship shown in Fig 6.4 is taken from the London noise survey.

6.2.14 This allowance may be deducted depending on the proximity of the site boundaries to the various classes of road. On urban sites where there is likely to be general noise contamination from a variety of sources, the variation from the quiet to the noisy side of the building is not likely to exceed 5 dB. In some situations, e.g. rooms facing small internal courtyards, the building may provide a degree of shielding greater than 5 dB. On rural sites, where one side of the building points on to a frequently used road which forms the dominant noise source, similar variations can occur. If in doubt take an interpolated value.

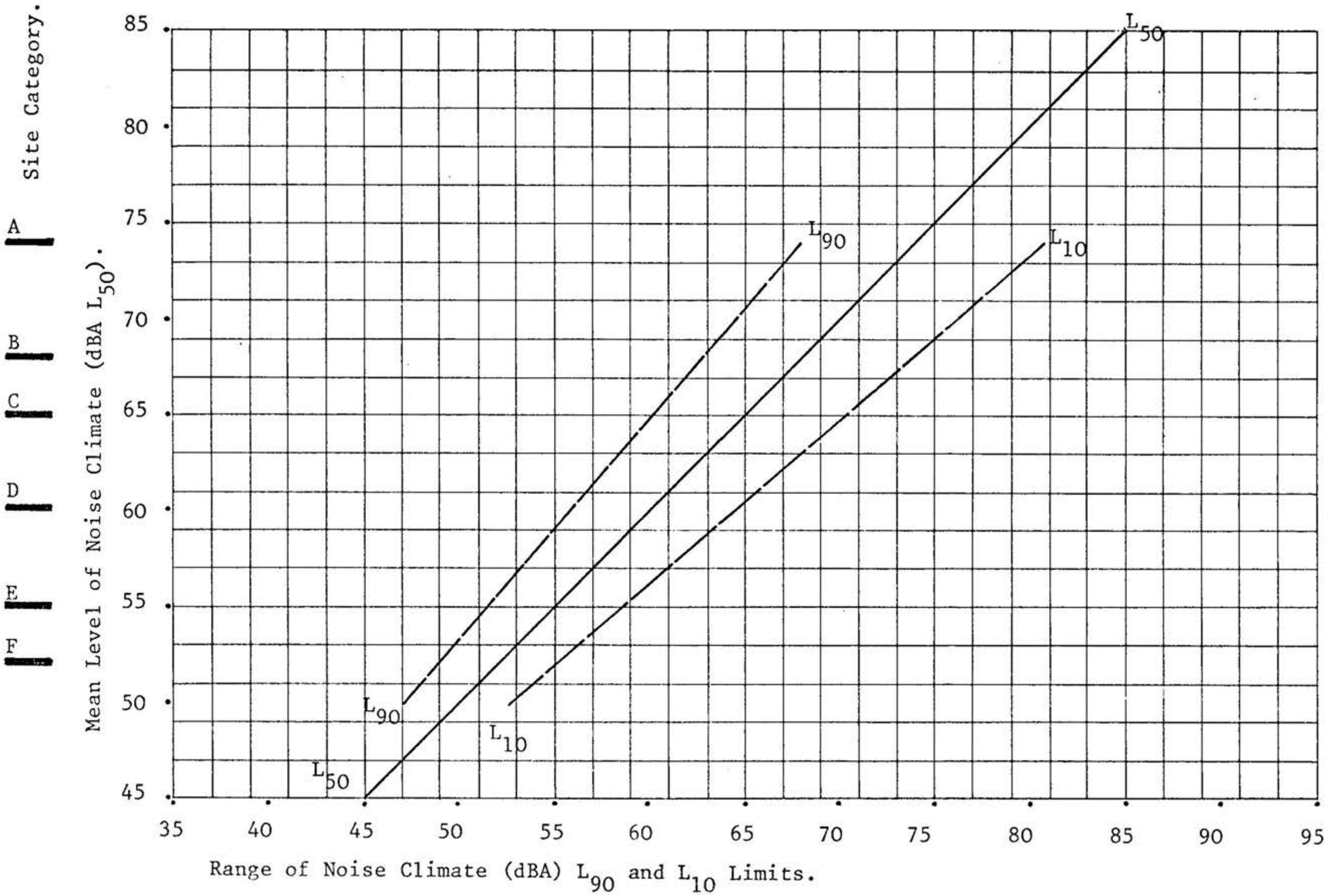


FIG 6.4 PROBABLE RELATIONSHIP BETWEEN MEAN LEVEL FOR AN EXTERNAL NOISE CLIMATE (dBA L_{50}) AND L_{10} AND L_{90} LIMITS (from the London Noise Survey).

6.2.15 Sound reduction values of closed windows.

WINDOW TYPE	dB
Closed 'openable' single window	19
Sealed single window (3-4 mm glass)	24
Sealed single window (6 mm plate glass)	27
Sealed single window (9 mm plate glass)	30
Ventilated double window (5% area of indirect ventilation)	18
Closed 'openable' double window (any weight of glass with an air space of 200 mm and absorbent lined reveals)	31
Sealed double window (4 mm glass with air space of 200 mm and lined reveals)	40
Sealed double window (6 mm glass with air space of 200 mm and lined reveals)	42

6.2.16 Refer to BS Code of Practice CP3: Chapter III Part 2 (1972), or the NPL Airborne Sound Insulation of Partitions (see also note 6.2.08).

6.2.17 Divide the area of solid wall by the area of the window.

6.2.18 Obtain the net insulation of the external wall from Fig 6.3 using the values recorded under 6.2.15, 6.2.16 and 6.2.17.

6.2.19 N.B. If the value obtained by the summation as described in 6.2.19 (A) exceeds 42 dBA in consulting rooms, complaints may arise due to excessive background noise.

ALTERNATIVELY, if the value in waiting and reception areas exceeds 52 dBA, the building may appear excessively noisy to occupants and make telephone conversations difficult at the reception desk.

6.2.20 If the resultant plot falls only two or three decibels short of the criterion line, there will be a marked loss of speech privacy if the listener is in an attentive state. In practice both practitioners and patients actively engaged in consultation will tolerate appreciably lower standards, as suggested by the tentative correction factors of 6.2.05 and 6.2.06 and the tolerance zones shown on the various graphs.

VII ADDITIONAL PLANNING CONSIDERATIONS AND NOTES ON CASE STUDIES.

7.1 General.

In the previous chapter it is suggested that spatial relationships and constructional details should be systematically examined, in relation to the criteria following from field trials and laboratory experiments. Although, at first sight, this procedure may appear to be very time consuming, with practice typical sets of circumstances can be identified and evaluated rapidly; assuming that all the necessary data is to hand.

To illustrate the utility of this procedure the buildings selected for case studies are subjected to further scrutiny in section 7.2. Some of the more typical room relationships are examined, using the predictive method and associated data. In addition, more general observations following from the visits already described are noted, and attention is also drawn to possible interactions between sound insulation and other environmental factors.

7.2 Sound isolation between consulting rooms in alternative plan forms.

Typical consulting room relationships are illustrated in Figs 7.1a, b and c. The first layout is the one most frequently encountered in the more recent health centres and outpatient departments in Scotland.[74] Fig 7.1b shows an alternative form in which separate examination rooms are placed between consulting rooms.[75] A variation of the latter consists of alternative consulting and examination rooms as shown in Fig 7.1c.

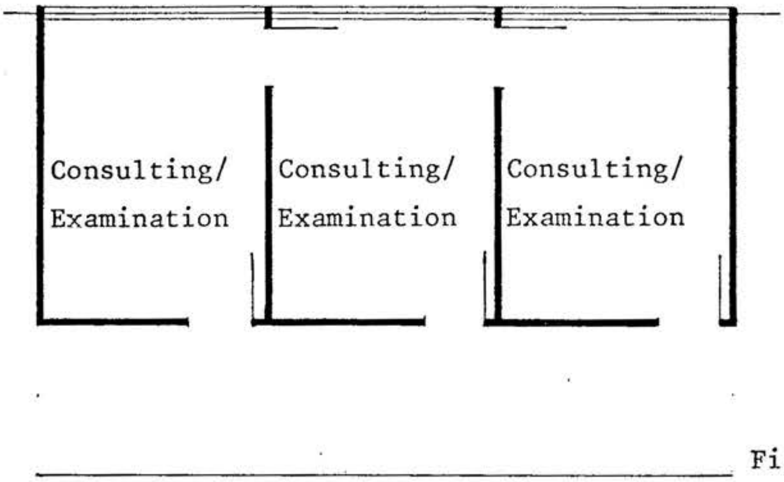


Fig 7.1a

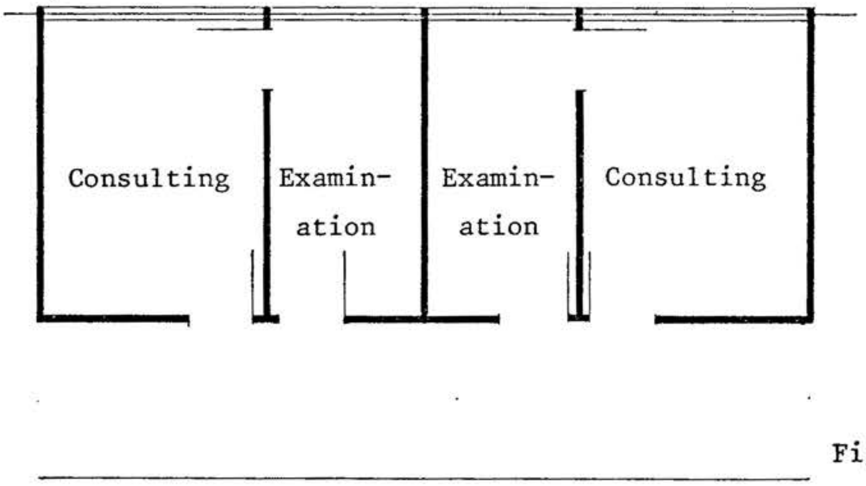


Fig 7.1b

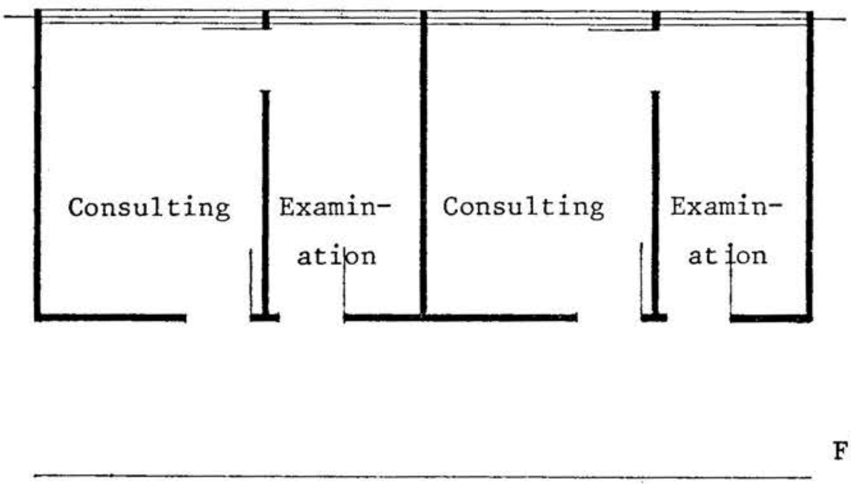


Fig 7.1c

FIGS 7.1a, b & c. TYPICAL PLAN RELATIONSHIPS OF CONSULTING ROOMS.

Of the three basic possibilities, conditions established by (b) and (c) are the most critical with regard to speech privacy. In either of these arrangements a patient may be waiting in the examination room whilst another patient is in consultation with the doctor. In these circumstances the waiting patient is in a highly attentive state, with nothing to distract his attention from the conversation in the adjacent room.[76] Almost invariably, the intervening partition incorporates a single, relatively lightweight, door.

An analysis of the situation at Woodside illustrates the probable consequence. Initially, the sound insulation of the basic 4½" brick and plaster partition was determined at 48 dB (Ia rating). This drops to 29 dB when a medium weight flush door is incorporated. (In a wooden frame without seals.) The L_{50} level in both examination and consulting rooms was approximately 32 dBA with windows closed and 40 dBA with windows open.

It will be seen from Fig 7.2a that whilst the brick partition without a door provides a good degree of speech privacy in ambient noise climates from 29 dBA upwards, when the door is included it falls short of the criterion by approximately 15 dB. It is interesting to note however, that in a building with this plan form the deficiency may only become apparent to the patient who is left alone in the examination room: the doctors themselves may be unaware of the problem.

Predictions for the buildings at Dumbarton and Falkirk are also plotted on the same diagram. These incorporate communicating doors between adjacent consulting rooms, as in Fig 7.1a. Dumbarton, with double doors and efficient seals fitted in the

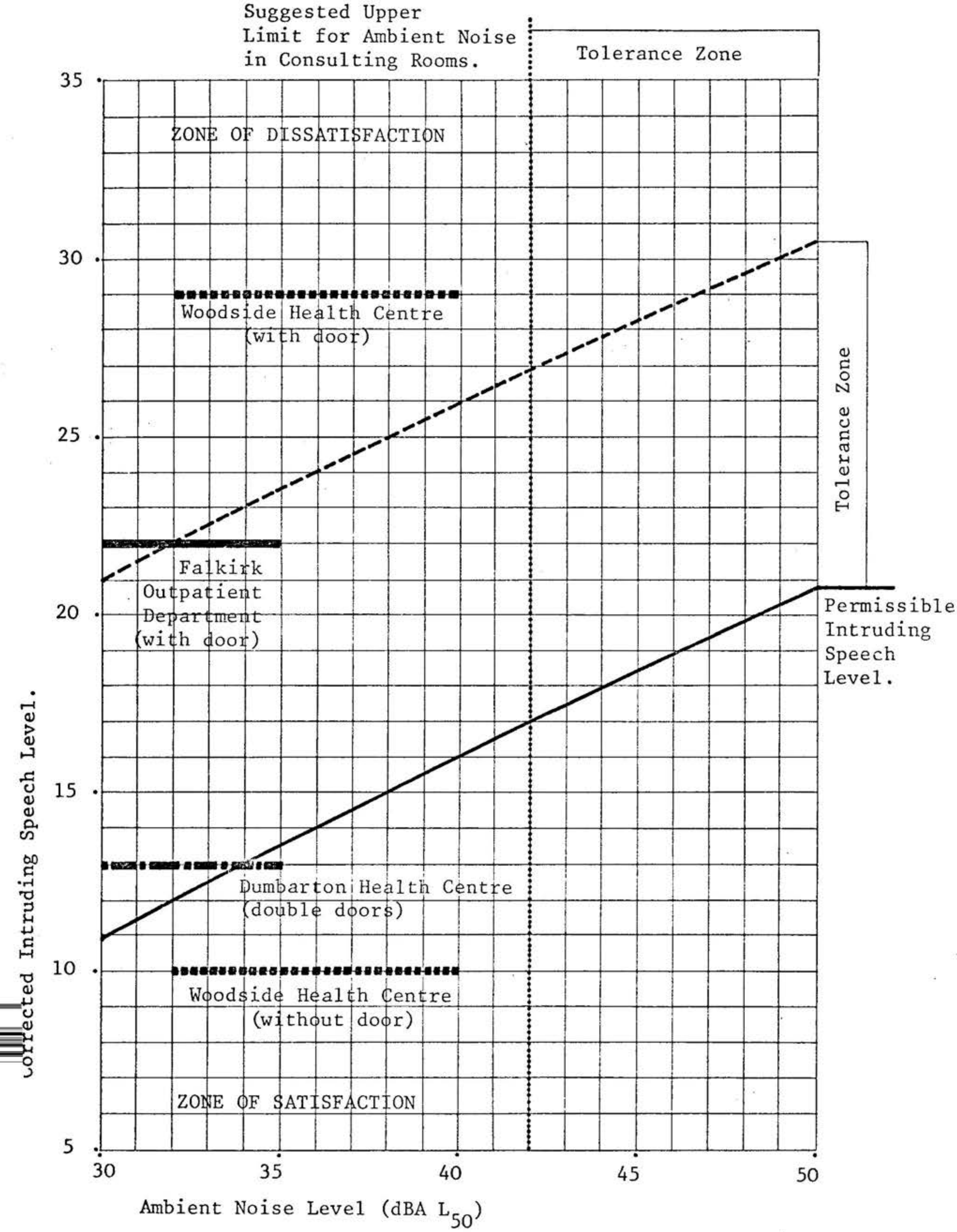


FIG 7.2a PREDICTION OF OCCUPANTS' RESPONSES, FOR THE THREE BUILDINGS SELECTED FOR CASE STUDIES, USING MEASURED SOUND INSULATION AND AMBIENT NOISE DATA.

CLASP 4B partition (Ia rating 43) and an ambient noise level of of 30 - 35 dBA, is only 1 dB short of the 95% confidence limit which forms the criterion.

Falkirk outpatient department, with a somewhat lighter partition incorporating a very heavy door fitted with double seals, provides an Ia rating of 34 dB. Although this falls short of the criterion by approximately 9 dB and could give rise to some dissatisfaction, it lies on the edge of the possible tolerance zone. Furthermore, in this plan form the patient is unlikely to be left unattended.[77]

It is also interesting to compare the performance of the buildings at Falkirk and Woodside. Although laboratory tests show that the basic sound insulation of the plasterboard and stud partition at Falkirk is substantially below that of the brick partition of Woodside, in practice the loss of speech privacy can be more acute in the latter building.

7.3 Sound insulation between consulting rooms and adjacent corridors and waiting areas.

Fig 7.2b shows that the sound insulation problem may be just as acute between the consulting room and the corridor, the most critical condition occurring when quiet internal waiting rooms are in close proximity to consulting room doors (Fig 7.3a). This condition occurs in the Dumbarton health centre. Even in some situations where they are not in close proximity, if all of the corridor surfaces are reflective, the corridor itself will act as a transmission line over considerable distances with a resulting loss of privacy (Fig 7.3b). The most effective solution particularly in health centres is to treat the corridor as a sound lock, although this may be undesirable

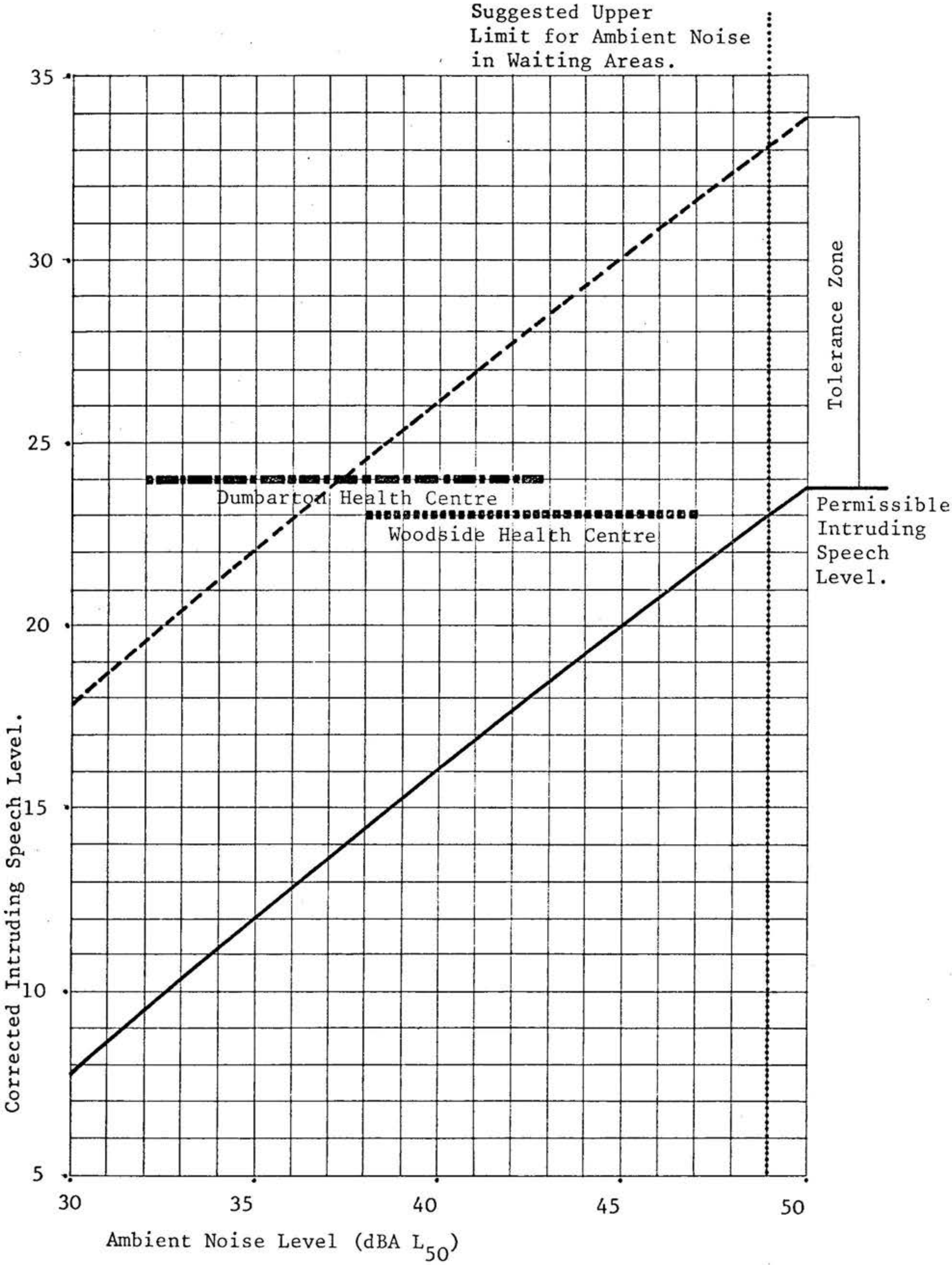


FIG 7.2b PREDICTION OF OCCUPANTS' RESPONSES, FOR THE THREE BUILDINGS SELECTED FOR CASE STUDIES, USING MEASURED SOUND INSULATION AND AMBIENT NOISE DATA.

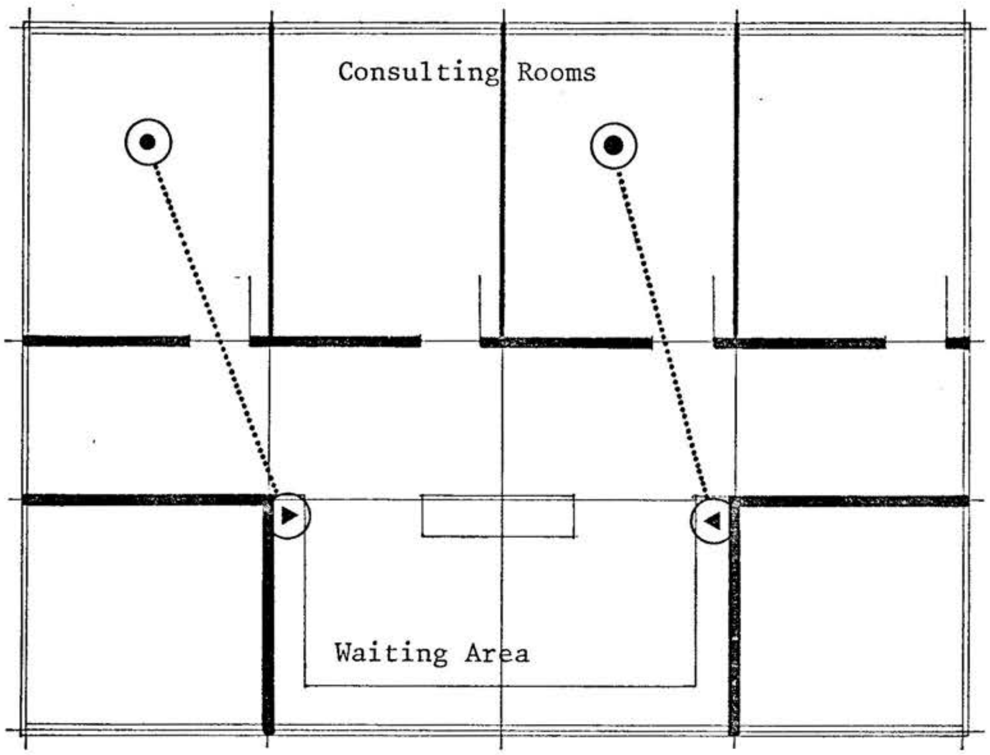


FIG 7.3a

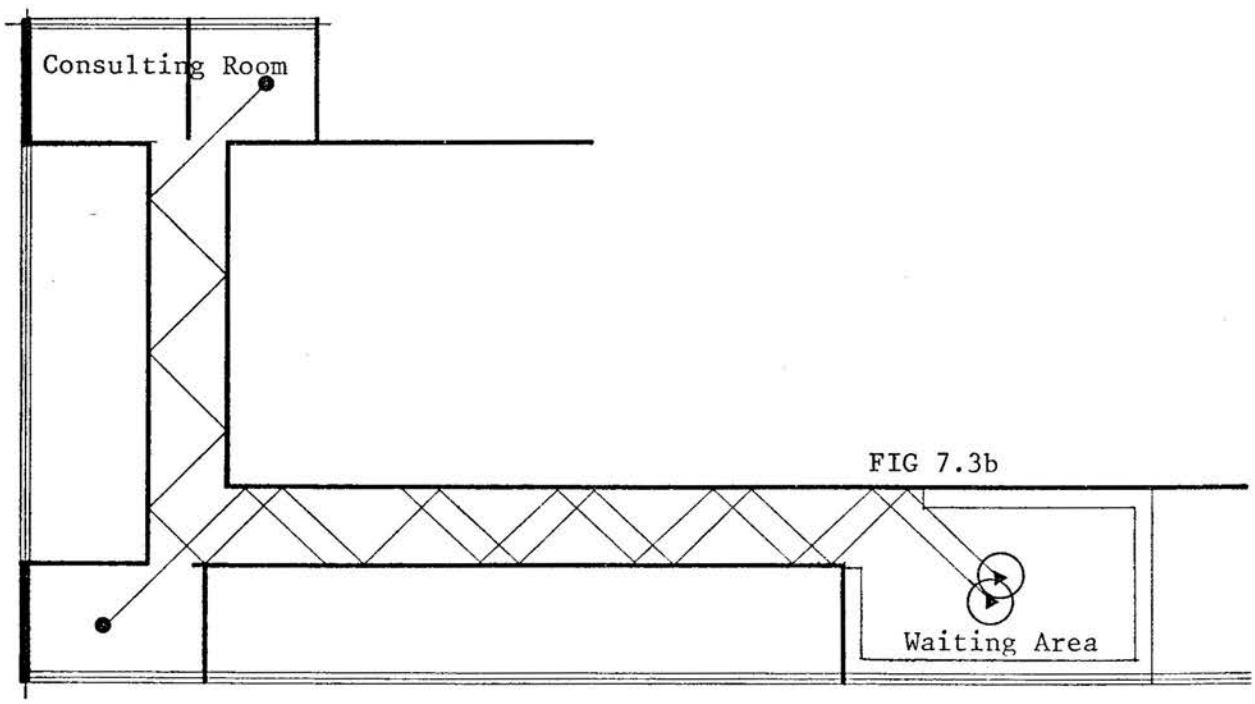


FIG 7.3b

FIG 7.3a & b. PLAN RELATIONSHIPS LEADING TO LOSS OF SPEECH PRIVACY BETWEEN CONSULTING ROOMS AND WAITING AREAS.

from other points of view. A simple form of sound baffle should be used in conjunction with as much sound absorption in the corridor as possible, to reduce this transmission line effect.

7.4 Ventilation.

It is apparent that, with the more open form of plan, the performance of the building may fall short of the proposed criteria unless efficient seals are placed on all doors. This measure will in turn influence the rate of air change in the consulting room. Wise has suggested that ventilation rates can drop to 0.15 air changes/hour if windows are fitted with weatherstrips to reduce heat loss in winter;[78] providing door seals throughout may have a similar effect.

Very low ventilation rates can mean that odours are not dispersed rapidly enough and lead to overheating in mid-summer. The latter will tend to occur if large south facing windows are provided, with a low ratio of opening lights; the problem can be acute if the building has a low thermal capacity, as is the case with most industrialized building systems.[79]

In most cases it will be possible to compensate for the reduced ventilation rate by a) keeping window areas to the minimum required for adequate daylighting, thereby minimizing solar heat gain and b) increasing the ratio of opening to fixed lights. If the external noise level is too high to permit adequate natural ventilation via the window, then a suitable air exchange system should be envisaged in the early design stages.[80]

7.5 Additional planning requirements for aural privacy.

While the primary object of this report is to deal with the provision of an adequate degree of speech privacy between rooms, discussions with occupants of various health centres have shown that dissatisfaction may also arise due to telephone conversations, between receptionists and patients, being overheard by patients in waiting areas.

In practice it may be difficult to completely obviate this, but careful planning and detailing will minimize the problem. As much sound absorption as possible should be placed in the immediate proximity of telephonists to reduce the speech level. Glazed screens may also be required between reception desks and waiting areas which are in close proximity to each other.

Reverberant corridors can again act as transmission lines to relay telephone conversations and in one of the health centres visited, conveyed conversations at an articulate level from the reception desk to waiting areas on the opposite side of the building. This again suggests that extensive sound absorption should be provided in corridors.

In general, the buildings used for field measurements and noise climate analysis incorporated top-hung windows. At an early stage of the research, comparative measurements (in a school) indicated that the loss of sound insulation due to slightly open windows (normal condition) was approximately 3 dB. This figure relates to the normal sound insulation performance in the field of the CLASP Mk 4B partition.

In practice, this reduction of insulation is offset by the rise in ambient noise level due to increased traffic noise through the open window, this being of the order of 6 - 9 dBA. It is important, however, that windows in adjacent rooms are not in close proximity; a critical loss of privacy could occur if side hung casements were used, hung on opposing sides so that, when opened, they acted as complementary reflectors between rooms.

VIII CONCLUSION

8.1 General.

The field trials and laboratory experiments have shown that the minimum 40 dB empirical insulation standard BS CP Ch III provides a satisfactory degree of speech privacy in normal circumstances. This 40 dB standard is valid for most of the ambient noise levels which may be encountered in consulting rooms, assuming that the slope of the insulation spectrum is classified as B or C. An additional factor of safety of 5 dB is provided by the 45 dB standard; this gives further protection against raised voices, fluctuations in background noise and listeners with acute hearing.

Many building occupants are apparently satisfied with partitions providing lower insulation values than those indicated in the previous paragraph; this can be attributed to one or more of the factors described in the main text. Widely differing opinions can emerge between doctor and patients, as well as between members of the same group, in identical circumstances. Although insulation values 9 - 10 dB below those suggested by the criteria graphs may be tolerated by some users, a definite loss of speech privacy will occur at times.

The investigations which are reported in Chapters IV and V show that lightweight metal faced plasterboard partitions can effectively meet these user requirements, although the airborne sound insulation value (R') may be below the actual standards of BS CP3 Ch III. This is due to the particularly efficient shape of the insulation spectrum. The latter is taken into account if the Ia rating procedure of ISO R717 is used.

If, say, in health centres a 5 dB higher standard is deemed necessary, tests at Paisley have shown that the Mk 5 partition will still be adequate provided that careful attention is paid to sealing at the bulkhead. Whenever a single door is incorporated it is unlikely that the overall insulation will exceed an Ia rating of 35 however efficient the partition may be. This assumes the use of a very heavy door with double seals, coupled with careful on-site fitting and supervision. This means in effect that the use of a single door can only be completely satisfactory in outpatient departments, in the more noisy locations. In health centres, and particularly where ambient noise levels are low, double doors are desirable. The use of a separating lobby and absorption between doors, as suggested in BS CP3 Ch III is not essential, providing that reasonably heavy doors and efficient seals are used and carefully fitted. The use of double doors may inhibit movement between rooms. An effective compromise solution could be to select suitable ironmongery to allow one door to be locked back against a wall, leaving a single door for clinics and similar activities. When the consulting rooms are used for general practice consultations, both doors would be closed.

Extensive trials at various locations have shown that high standards of workmanship must be aimed at if an adequate performance is to be achieved. Doors and door seals must be closely fitted to achieve an Ia rating of 35 dB from the composite partition. None of the buildings studied, when this door construction was specified achieved 35 dB on first inspection.

Detailed instructions regarding construction and tolerances should, whenever possible, be presented directly to the man who will carry out the work and subsequent site inspection of every door may be required. Experience gained during the field experiments indicates that doors fitted with efficient seals can be difficult to close, particularly in light and relatively flexible frames and partitions. The use of a simple form of feeler gauge, to ensure that the seals are in light but positive contact, minimises this problem. It is also essential that door frames are substantial and rigidly braced.

Long term maintenance is another aspect which must be carefully considered as both wear of seals and warping of doors can render the seals inefficient. Some degree of warping is unavoidable if wooden doors are used and the design and fitting of door seals must allow for this.

A comparative examination of the criteria graphs shows that under some conditions speech privacy requirements can be more demanding between consulting rooms and corridors and waiting areas, than between adjoining consulting rooms. Ideally, from the acoustic point of view, corridors giving access to consulting rooms should be isolated from waiting areas by double doors, although this may be undesirable for other reasons. At the very least, some form of sound baffle should be incorporated, in conjunction with the liberal use of absorbent materials in the corridor. If a patient is allowed to wait in close proximity to a consulting room, the latter having a single entrance door, a serious loss of speech privacy may result. This will be inevitable if the ambient level in the waiting zone is low, as was typical in the internal individual practice waiting areas in the Dumbarton health centre.

The broad integrative nature of the present research has inevitably placed severe constraints upon the extent and depth of study in any one section. The limitations of each aspect of the work are discussed in the following paragraphs, with a view to identifying areas of future research.

8.2 Laboratory experiments.

The correlation of stability coefficient between laboratory experiments 1.b and 2.b suggests that the basic experimental format was reliable. It would seem worthwhile therefore, to extend the sample by using a much larger group of subjects which would be more representative of the population. Age range was too restricted in the initial group, varying from 33 to 55 years. It may also be desirable to choose subjects to reflect regional variations associated with dialect and similar factors. The test tape was deficient in this respect. Only two very articulate speakers were prerecorded, one male and one female, although there were randomized variations in other respects, as shown in table 2.1.

To maximize the use of subjects' time, the test passages could be made shorter on average. This would yield a larger number of responses in a given time. As a corollary, it would be essential to improve the sound isolation of the test chamber.

The instrumentation could be modified in several respects. Although the attenuator was highly accurate and capable of 0.1 dB steps, it was clumsy to manipulate and noisy when switching. Furthermore the subject was required to read and note the instrument settings.[81] A more sophisticated form of attenuator can be envisaged which would give no indication to the subject but a digital read-out to the experimenter. This reading could be punched directly on to paper tape for computor analysis, upon receipt of a command signal from the subject.

An actual partition, in addition to attenuation, introduces a complex pattern of phase changes in relation to frequency, which was not reproduced in the laboratory simulation. The simulation may be improved by using a network of speakers in the imaginary partition plane, and electronically introducing appropriate phase changes to each individual speaker.[82]

As intimated by table 2.1 linear regression analysis was performed on the blocks of data, following a preliminary graphical analysis to indicate the order of importance of the independent variables. A larger scale and more sophisticated form of experiment would necessitate the use of multi-factorial and possibly curvilinear regression analysis.

8.3 Possible technical developments.

A number of detailed technical developments, relating to the insertion of special doors and ceilings in to the CLASP system, have been described in section 4.5. An additional change, which should theoretically upgrade the performance of the basic partition, would be to include some form of absorbent in the cavity. It would also seem desirable to vary the thickness of plasterboard on alternate sides of the partition. In practice the gains may only be marginal and could be largely negated by flanking transmission. The cost of the partition would inevitably be increased, as would be the number of partition components required. Nevertheless, in special circumstances, when the utmost degree of privacy is sought these changes may be desirable, with associated measures to reduce the flanking transmission.

A more fundamental issue arises when further consideration is given to the use of electronic masking systems, particularly in relation to the more open form of plan.

In recent years there has been a trend, particularly in health centres towards this type of plan. An inspection of the Figs 3.1 - 3.3 should reinforce this point. These three buildings are typical of practically all others visited, in that no isolating doors are provided between waiting areas and the corridors which provide access to consulting rooms. The reason for this is only partly aesthetic. It is evident from the various publications dealing with medical practice that doctors themselves attach considerable importance to ease of access; movement is impeded if double doors are used to establish a physical sound lock.

The limited potential of conventional electronic masking systems to increase isolation between consulting rooms has already been discussed in section 3.4. The objections raised in that section do not necessarily apply to situations between consulting rooms and access corridors. In the open plan, the use of loudspeakers with marked directional properties, located in corridor ceilings in the region of consulting room access doors, may provide adequate isolation without the use of double doors.

A further refinement, which may also make such a system suitable for situations between consulting rooms, would involve the use of a transducer (either microphone or loudspeaker), to sense the presence of speech in the consulting room. Loudspeakers, located in adjacent rooms and corridors, would then be coupled to an ambient noise circuit by relays or similar devices. The resultant effect would be a 'sound blanket' around the critical zone. Providing that the noise spectrum was carefully shaped and the rate of increase of the ambient level controlled, it is unlikely that masking noise introduced in this way would be noticed by the building occupants. The presence of the partition should minimize problems which might arise due to acoustic feedback between the transducers.

The alternative approach, of placing other forms of transducer on the actual wall panels, with the object of driving panels out of phase, at first sight appears more costly and also less likely to succeed.

These are of course purely tentative proposals for developments of a technical nature. Nevertheless the electronic installation in the Royal Festival Hall has demonstrated, albeit to a limited extent, the potential of electronically controlled systems to modify the acoustic environment.[83] Further exploration in this field would seem desirable.

8.4 Implementing and improving the predictive method.

There are two basic approaches to the implementation of building standards. A precise set of conditions may be laid down, with the stipulation that the building designer should, or must, comply. Alternatively, the designer can be trained to analyse the needs of users, to establish suitable performance standards and to select or innovate forms of construction as required. This trend in building regulations and performance standards has emerged in recent years.

The predictive method of Chapter VI may be used for either purpose. On the one hand it can be used to delineate one or more sets of conditions, including both planning and constructional factors, which, if met, should guarantee an adequate degree of speech privacy. On the other hand, it is a procedure to alert the designer to the various facets of the problem and to encourage innovation; at the same time, it is a control tool to ensure that the innovation is not irresponsible.

The predictive method may be developed in two ways. The first is by incorporating the results of more specialized research, relevant to the various sub-sections, as they become available. The second is to use statistical decision theory to integrate all aspects.

It would be much easier presumably, for a group of medical advisors who are formulating a standard, to agree upon the magnitude of the factor of safety if lack of speech privacy could be expressed in terms such as frequency of occurrence, e.g. one occasion, involving several words or part of a conversation overheard, may be acceptable for every hundred consultations. Simple probability theory might then be utilized, even at the present state of development of the predictive method.

The criteria curves of Chapter II are computed as 95% confidence limits for the mean and may be taken as upper 50% tolerance limits for individual responses. The insulation values for the CLASP Mk 4B system quoted in table 4.1 (column 3) at -1 standard deviation effectively constitute an 84% tolerance limit. Similarly the L_{50} dBA measure of noise climate may be considered as a 50% tolerance limit, with the proviso that the sample is reasonable large and an appropriate normalizing procedure is applied.

If these three major variables are treated as empirical independent probabilities, the multiplicative law of probability suggests a frequency of occurrence of four privacy failures in every hundred consultations, or one in twenty five. This would not of course meet the projected one in one hundred criterion.

Theoretically this particular analysis is only valid for a stationary listener in a critical listening zone. If the plan form places every visitor in such a position, it would be necessary to adopt the L_{90} dBA ambient noise level as the masking level when calculating the insulation required. This would then change the potential frequency of occurrence to eight times in one thousand and as such would meet the proposed standard.

More usually however the plan form can be designed to minimize the probability of the patient waiting in a critical listening zone. Although no specific data is available a reasonable assumption would be that in the better plans a patient finds himself in a critical zone say once in every ten visits. This would mean a potential frequency of failure of one in two hundred and fifty, again meeting the tentative standard whilst retaining the L_{50} masking level for the purpose of calculation. It would seem desirable therefore, if statistical decision theory is to be adopted, to obtain ancillary data regarding the probability of a patient waiting in various listening zones, in relation to particularly sensitive consultations, for alternative plan forms.

APPENDIX I GLOSSARY

dBA	The unit of measurement of sound level, using frequency weighting network A.
AIRBORNE SOUND INSULATION.	The quantity to be measured is $$R' = L_1 - L_2 + 10 \log \frac{S}{A} \text{ dB}$$ where, L_1 is the average sound pressure level in the source room; L_2 is the average sound pressure level in the receiving room; S is the common surface wall or floor area between the two rooms; A is the equivalent absorption area of the receiving room. N.B. The transmission loss for field measurements is designated R'. Similar measurements, taken under laboratory conditions (excluding flanking transmission) are designated as R.
AIRBORNE SOUND INSULATION INDEX (Ia),	This is the single figure in terms of which the effective airborne sound insulation performance is evaluated. (For full definition see ISO R717 1968.)
DECIBEL.	The decibel scale refers to logarithmic ratios of sound pressure, the basic unit of pressure being the dyne per square centimetre. The range to which the ear responds is very large, namely from 0.0002 dyn/cm^2 (0 dB reference level) to approximately 1,000 dyn/cm^2. The corresponding decibel range is 0 - 134 dB. In subjective terms, an increment of one decibel

at any point of the scale is a just noticeable difference and 10 dB roughly corresponds to a doubling of loudness. Thus 70 dB is twice as loud as 60 dB, and 60 twice as loud as 50 dB.

DYNAMIC RANGE. In the context of the present study is the difference between the upper and lower limits of sound pressure level for a sound source which is vaying with respect to time, e.g. speech.

EFFECTIVE MASKING LEVEL. Noise has the effect of reducing the acuity of hearing; that is, it elevates the threshold of audibility. This shift in threshold of audibility is called masking. Masking data are sometimes represented in the form of a curve called a masking spectrum or audiogram. This shows the number of decibels at each frequency that the threshold level of a pure tone is shifted, when heard by a normal observer in the presence of masking sounds.

In the present document the term "effective masking level" refers to the measured dBA L_{50} level at which noise with a spectrum similar to the Noise Rating 25 curve effectively prevents the articulation of intruding speech.

FREQUENCY WEIGHTING NETWORK. An electrical network, which may be switched into the amplifying circuits of a sound level meter, to produce a specified overall electro-acoustic frequency response which approximates to the human auditory response. Three such networks are normally incorporated, designated A, B and C. A is the one most widely used.

LOUDNESS AND LOUDNESS LEVEL. Loudness differs from loudness level, although they are related logarithmetically. Loudness refers to the subjective magnitude of a sound as judged by the normal listener. The unit is the sone. The loudness level of a given noise is defined as the sound pressure level of a pure tone at 1,000 Hz which appears equal in loudness to the noise being rated. The unit is the phon.

For methods of calculating loudness see British Standard 4198:1967.

NOISE RATING CURVES.

Various noise criteria curves have been used to indicate limits to noises in buildings, bearing in mind the sensitivity of typical room functions. Three of the most widely used are the Noise Criterion (N.C. 1957), Noise Rating (N.R. 1965) and Preferred Noise Criterion (P.N.C. 1971) curves. These show decibel limits in relation to frequency bands. A noise is stated to have a Noise Rating given by the number of the standard curve which lies just above the frequency spectrum of the intruding noise when the latter is plotted on the standard graph paper.

In practice, for traffic noise the dBA criterion has been found to be just as accurate and simpler to measure and administer. Frequency analysis and use of noise rating curves are only required when the noise spectrum is unusual.

NORMALIZED LEVEL DIFFERENCE.

Is used to describe the sound insulation properties of a partition when measured under field conditions. The results of measurements are normalized so that insulation value quoted relates to a standard amount of absorption in the receiving room. See B.S. 2750:1956 or ISO R140.1960.

REFERENCE LEVEL.

The sound pressure level corresponding to a r.m.s. sound pressure of 0.0002 dyn/cm^2 (= 0 dB).

REFLECTIVE SURFACE.

The sound absorption coefficient (α) is defined as the ratio of the sound energy absorbed by a surface to the sound energy incident upon that surface when the sound field is diffuse. Accordingly α may take on numerical values between 0 and 1. In this document the term reflective surface refers to lining materials with an average sound absorption coefficient of 0.1 or less.

REVERBERATION TIME. Is the time required for a specified sound to die away to one thousandth of its initial pressure, which corresponds to a drop in sound pressure level of 60 dB.

SOUND ABSORPTION. Refers to the total sound absorption characteristics of a room or space. Objects such as chairs, seats, tables, desks and people must be included when calculating $\bar{\alpha}_{Sab.}$ by the formula

$$t_{Sab.} = \frac{0.16\ V}{\bar{\alpha}\ Sab.}$$

where $t_{Sab.}$ = reverberation time calculated according to Sabine's formula.

V = the total volume of the room

and $\bar{\alpha}$ = the sum of all absorption units in the room.

N.B. The effect of absorption in air is not significant at speech frequencies, if the room volume is similar to that of the normal consulting room, and is not therefore incorporated in the formula.

SOUND BAFFLE. A projecting wall or screen which diverts sound waves which would otherwise be radiating directly from the source.

SOUND INSULATION. Is synonymous with the term isolation when two spaces are adjacent.

SOUND ISOLATION. A generic term used in the present document to describe the overall degree of insulation between two spaces which may or may not be adjacent to each other.

SOUND LEVEL METER.	An objective noise meter designed to measure the sound pressure level, with the insertion of a frequency weighting network if required.
SOUND LOCK.	A lobby or similar space with separate entrance and exit doors and providing a high degree of sound isolation.
SOUND PRESSURE LEVEL.	20 log (p/p_0) decibels, where p is the r.m.s. sound pressure, and p_0 is a reference sound pressure, usually 0.0002 dyn/cm^2.
SOUND REDUCTION INDEX.	Describes the sound insulation properties of a partition when measured under standardised laboratory conditions. See B.S. 2750;1956 or ISO R140. (N.B. In American terminology it is referred to as the transmission loss.)
SOUND SPECTRUM.	A sound may be analysed by filters of octave or 1/3 octave bandwidth, and the sound pressure level plotted in decibels for each band. The resulting graph is referred to as the sound spectrum, which illustrates the spectral characteristics of that particular sound.
SPEECH INTERFERENCE LEVEL (PREFERRED SPEECH INTERFERENCE LEVEL).	Is based on the science of speech communication and rates steady noise according to its ability to interfere with conversation by taking the average in decibels of the sound pressure levels in the octave bands centred on 500, 1000 and 2000 (Hz). N.B. The original speech interference level (SIL) was based on the octave bands 600 to 1200, 1200 to 2400, and 2400 to 4800.
TRANSMISSION LINE.	A vehicle for conveying sound or electricity with minimum energy loss.

APPENDIX II RELATIONSHIP BETWEEN dBA AND ALTERNATIVE METHODS OF NOISE RATING.

This table is only an approximate guide, as the precise relationships depend on spectral characteristics and variability of noise climate.

N.C. or P.N.C.	N.R.	L_{10}	dBA L_{50}	L_{90}	N.P.I.	T.N.I.
10	11		21			
15	16		26			
20	21	34	30	26	39	28
24	25	38	34	30	43	32
29	30	42	38	34	47	36
34	35	45	42	39	49	33
39	40	50	47	44	54	38
44	45	55	52	49	59	43
49	50	60	56	52	65	54
54	55	65	61	57	70	59
59	60	71	66	61	78	71

N.C. - Noise Criterion (1956)
P.N.C. - Preferred Noise Criterion (1971)
N.R. - Noise Rating (1965)
T.N.I. - Traffic Noise Index (1968)
N.P.I. - Noise Pollution Index (1970)

APPENDIX III BASIC DATA FOR NOISE CLIMATE ANALYSES AT THE WOODSIDE AND DUMBARTON HEALTH CENTRES.

L_{10}, L_{50} and L_{90} levels, derived by probability distribution analysis with a sample count of 400, at 0.1 second intervals, each sample extending over 40 seconds.

Time	9.08	9.16	9.24	9.32	9.40	9.48	9.56	10.00	10.08
L_{90}	38.0	39.0	38.0	38.5	40.0	38.5	39.5	38.5	38.0
L_{50}	41.0	42.0	41.0	42.0	42.5	41.0	42.5	41.5	40.0
L_{10}	46.5	47.5	47.5	47.5	47.5	44.5	49.5	50.0	43.5
	10.16	10.24	10.32	10.40	10.48	10.56	11.00	11.08	11.16
	38.0	38.5	40.5	38.5	43.0	40.0	39.0	40.0	40.5
	40.5	41.5	43.0	41.5	46.5	43.5	41.5	43.0	42.5
	44.5	44.5	48.0	44.5	52.0	49.0	45.5	49.0	47.0
	11.24	11.32	11.40	11.48	11.56	12.00	12.08	12.16	12.24
	40.0	40.5	41.0	39.0	40.5	38.0	40.0	40.5	40.0
	44.5	44.5	44.0	43.0	44.5	41.5	44.0	45.0	43.5
	48.5	51.0	47.5	48.5	51.5	50.0	48.0	54.0	48.5
	12.32	12.40	12.48	12.56	13.00	13.08	13.16	13.24	13.32
	39.5	45.0	40.0	38.5	36.0	36.5	38.0	36.5	38.5
	44.0	50.5	44.5	42.0	39.5	39.0	41.0	39.5	41.5
	51.5	56.0	52.5	49.5	45.0	42.0	47.0	44.0	45.0
	13.40	13.48	13.56	14.00	14.08	14.16	14.24	14.32	14.40
	38.0	36.0	37.0	36.0	39.0	38.0	38.5	37.0	37.5
	40.5	38.5	41.0	41.0	42.0	41.0	43.5	41.0	41.0
	50.5	42.0	47.5	47.0	45.0	46.0	50.0	50.0	47.0

TABLE 3.1a WOODSIDE HEALTH CENTRE (Internal microphone).

Time.	14.48	14.56	15.00
L_{90}	38.0	38.0	38.5
L_{50}	43.5	39.5	41.5
L_{10}	49.0	44.0	45.5

	14.24	14.36	14.48	15.00	15.12	15.24
	42.5	45.5	43.0	41.0	41.0	41.0
	56.0	49.5	46.5	43.5	45.0	44.0
	53.0	54.0	51.5	47.0	47.5	48.0

	15.36	15.48	16.00	16.12	16.24	16.36	16.48	17.00	17.12
	43.0	41.5	42.5	41.0	42.5	40.0	42.5	43.0	45.0
	47.5	49.0	48.0	44.0	47.0	44.0	45.5	56.5	49.0
	52.0	54.0	52.0	48.0	52.5	49.0	51.5	51.5	53.0

	17.24	17.36	17.48	18.00	18.12	18.24	18.36	18.48	19.00
	43.5	41.0	43.5	40.0	38.0	38.5	38.5	40.5	37.5
	50.5	44.5	48.0	45.0	40.5	42.0	41.5	42.5	39.5
	56.5	48.5	52.5	51.0	44.0	54.5	55.0	49.0	45.5

	19.12	19.24	19.36	19.48	20.00	20.12	20.24	20.36	20.48
	36.0	36.0	51.5	47.0	45.0	43.5	37.5	35.5	35.5
	39.0	38.5	53.5	59.0	47.5	46.0	39.5	38.0	36.5
	61.0	43.0	56.0	62.0	49.5	48.5	43.0	40.5	60.5

TABLE 3.1a (Continued).

Time.	21.00	21.12	21.24	21.36	21.48	22.00	22.12	22.14	23.24
L_{90}	35.5	35.5	35.5	35.5	35.5	37.5	36.0	36.5	35.5
L_{50}	36.5	37.0	36.5	36.5	37.0	39.5	38.5	39.5	36.5
L_{10}	37.5	39.5	38.0	39.0	40.0	45.0	40.0	44.0	40.0

Time.	23.36	23.38	00.00	00.12	00.24
L_{90}	34.0	34.0	33.5	33.0	33.5
L_{50}	36.0	36.0	35.5	35.5	36.0
L_{10}	37.0	37.5	37.0	37.0	37.0

Time.	11.12	11.24	11.36	11.48
L_{90}	39.0	39.5	36.5	39.5
L_{50}	47.5	43.0	40.5	42.5
L_{10}	57.5	47.5	46.5	47.0

Time.	12.00	12.12	12.24	12.36	12.48	13.00	13.12	13.24	13.36
L_{90}	38.5	37.5	41.0	39.5	37.5	38.0	36.0	39.0	38.0
L_{50}	41.5	40.5	45.5	44.0	40.0	41.5	39.0	42.5	41.0
L_{10}	46.5	45.0	51.5	50.0	44.5	50.0	44.5	51.5	46.0

Time.	13.48	14.00	14.12	14.24	14.36	14.48	15.00	15.12	15.24
L_{90}	37.5	36.0	36.0	37.5	38.0	36.5	37.5	38.0	39.5
L_{50}	40.0	38.5	38.5	40.0	40.5	39.0	40.0	40.0	45.0
L_{10}	44.5	42.5	41.5	60.5	50.0	42.5	44.0	44.5	59.0

TABLE 3.1a (Continued).

Time	15.36	15.48	16.00	16.12	16.24	16.36	16.48	18.00	18.12
L_{90}	40.5	36.5	38.5	39.5	38.5	39.0	38.5	40.5	40.5
L_{50}	45.5	42.0	41.5	41.5	41.0	42.5	42.0	43.0	43.5
L_{10}	50.5	49.5	45.0	45.5	46.5	48.0	52.5	47.5	47.5

	18.24	18.36	18.48						
	42.0	36.5	36.0						
	48.0	39.0	39.0						
	55.5	42.5	42.5						

				9.00	9.12	9.24	9.36	9.48	10.00
				35.5	35.5	35.5	35.5	38.0	38.5
				37.5	38.0	37.0	36.5	42.5	41.0
				41.0	39.5	59.0	39.0	52.0	44.5

	10.12	10.24	10.36	10.48	11.00	11.12	11.24	11.36	11.48
	38.0	39.5	38.5	38.5	38.5	37.5	39.5	41.5	42.5
	39.5	43.0	40.5	41.0	41.5	40.0	43.5	50.0	48.0
	42.5	46.5	44.5	44.0	45.5	44.5	52.0	61.0	55.0

	12.00	12.12	12.24	12.36	12.48	13.00	13.12	13.24	13.36
	38.0	40.0	38.0	39.5	38.0	38.5	39.5	40.5	38.5
	41.5	44.0	40.0	44.5	41.5	41.5	43.5	45.0	41.0
	49.0	49.0	45.0	52.0	46.0	47.0	49.5	52.5	44.5

TABLE 3.1a (Continued).

Time.	13.48	14.00	14.12	14.24	14.36	14.48	15.00	15.12	15.24
L_{90}	39.5	38.5	39.0	36.5	38.0	36.0	37.5	35.5	38.5
L_{50}	43.5	42.0	44.0	40.0	41.5	38.5	40.0	38.0	43.0
L_{10}	48.5	51.5	53.0	44.5	49.5	41.0	44.0	42.0	51.0

	15.36
	36.0
	39.5
	50.0

TABLE 3.1a (Continued)

Time.	9.08	9.16	9.24	9.32	9.40	9.48	9.56	10.00	10.08
L_{90}	61.0	58.5	60.0	59.5	60.0	62.0	58.5	56.5	61.0
L_{50}	66.0	64.0	63.0	65.0	63.5	66.0	62.0	60.5	63.5
L_{10}	69.5	68.5	69.0	70.5	67.5	68.5	68.0	67.5	66.0
	10.16	10.24	10.32	10.40	10.48	10.56	11.00	11.08	11.16
	63.5	64.5	64.5	57.0	59.0	62.0	60.0	63.5	62.5
	67.0	67.5	70.0	60.0	61.5	65.5	64.5	66.0	65.5
	71.5	71.0	73.0	74.0	65.5	69.5	68.5	69.5	68.5
	11.24	11.32	11.40	11.48	11.56	12.00	12.08	12.16	12.24
	61.5	59.0	60.0	58.5	59.5	58.5	59.5	63.0	63.0
	65.5	62.5	63.5	61.0	63.0	62.0	63.5	65.5	66.5
	68.5	69.5	68.0	64.5	66.0	65.5	67.0	70.0	71.5
	12.32	12.40	12.48	12.56	13.00	13.08	13.16	13.24	13.32
	35.5	62.0	67.0	63.5	59.5	59.0	57.0	61.5	56.0
	68.5	66.0	69.5	67.0	62.5	62.5	60.0	66.0	58.0
	71.0	69.5	73.0	71.0	67.5	67.5	66.0	68.5	61.0
	13.40	13.48	13.56	14.00	14.08	14.16	14.24	14.32	14.40
	63.0	59.5	59.0	59.5	53.0	63.5	57.0	60.5	37.5
	66.5	63.0	62.0	64.0	57.0	67.0	61.5	65.5	64.0
	70.5	78.0	79.0	68.5	62.0	70.0	66.5	69.5	69.0

TABLE 3.1b WOODSIDE HEALTH CENTRE (External microphone).

Time.	14.48	14.56	15.00						
L_{90}	58.5	62.0	58.0						
L_{50}	63.0	65.0	61.5						
L_{10}	68.5	67.5	66.5						

				14.24	14.36	14.48	15.00	15.12	15.24
				53.05	55.5	58.0	58.5	55.0	58.0
				57.0	62.5	50.5	62.0	59.5	60.5
				60.5	67.5	65.5	65.5	63.0	64.0

	15.36	15.48	16.00	16.12	16.24	16.36	16.48	17.00	17.12
	54.0	55.0	55.5	57.0	58.5	54.0	57.0	59.0	60.5
	59.5	60.0	59.0	60.0	61.5	60.5	60.0	61.5	62.5
	64.0	65.0	71.5	63.0	64.5	64.5	63.0	64.5	65.0

	17.24	17.36	17.48	18.00	18.12	18.24	18.36	18.48	19.00
	58.5	55.5	56.0	51.5	56.5	52.0	59.0	53.0	49.0
	62.5	69.0	60.0	58.0	62.0	57.0	62.5	60.5	52.0
	66.5	67.5	65.0	61.5	65.0	63.5	65.5	65.0	60.0

	19.12	19.24	19.36	19.48	20.00	20.12	20.24	20.36	20.48
	53.5	52.5	51.5	49.5	47.0	49.0	54.5	53.5	48.5
	59.0	58.5	57.0	54.0	50.0	51.0	59.0	59.0	51.0
	62.5	62.0	62.5	60.5	53.5	54.5	63.0	63.5	57.0

TABLE 3.1b (Continued).

Time.	21.00	21.12	21.24	21.36	21.48	22.00	22.12	22.24	23.24
L_{90}	46.5	52.0	50.0	36.0	47.0	59.0	55.5	56.0	49.5
L_{50}	49.0	56.0	55.5	43.5	54.5	61.0	59.5	60.0	53.5
L_{10}	56.5	61.0	60.5	49.0	60.0	65.0	63.5	64.0	59.5

	23.36	23.48	00.00	00.12	00.24				
	44.0	46.5	44.0	44.5	44.5				
	45.0	55.0	45.5	51.0	50.5				
	46.0	61.5	48.5	60.0	60.0				

						11.12	11.24	11.36	11.48
						63.5	63.5	59.5	55.0
						66.5	65.5	62.5	61.0
						70.0	69.0	65.5	69.5

	12.00	12.12	12.24	12.36	12.48	13.00	13.12	13.24	13.36
	59.5	56.0	60.5	58.0	58.0	61.5	59.5	60.0	61.0
	60.5	60.5	63.0	62.5	61.0	64.0	62.5	63.0	64.5
	65.0	64.5	67.0	68.0	65.5	68.0	65.5	67.0	68.0

	13.48	14.00	14.12	14.24	14.36	14.48	15.00	15.12	15.24
	51.5	57.0	50.0	61.0	51.0	67.0	67.0	55.5	51.5
	62.0	61.0	61.0	63.0	62.5	60.0	63.5	50.5	63.0
	65.0	65.0	64.5	65.5	66.0	65.5	66.5	64.5	68.5

TABLE 3.1b (Continued).

Time.	15.36	15.48	16.00	16.12	16.24	16.36	16.48	18.00	18.12
L_{90}	56.5	55.0	59.0	61.0	58.0	58.0	57.0	63.5	59.0
L_{50}	60.0	50.0	63.5	62.5	63.0	62.5	61.5	66.5	62.0
L_{10}	64.0	63.0	68.5	65.5	68.0	67.5	66.5	71.5	66.5

	18.24	18.36	18.48
	59.5	62.0	58.0
	63.0	64.0	62.0
	67.0	67.5	67.0

				9.00	9.12	9.24	9.36	9.48	10.00
				57.5	56.5	51.0	57.0	56.5	59.5
				61.5	61.0	64.0	60.5	59.0	62.5
				65.5	65.5	57.0	66.0	64.5	66.0

	10.12	10.24	10.36	10.48	11.00	11.12	11.24	11.36	11.48
	62.0	59.5	64.0	59.5	61.5	58.5	55.0	59.0	57.5
	64.5	62.5	66.5	63.5	64.5	61.0	61.5	62.0	61.0
	67.5	66.0	70.0	67.5	67.5	66.0	66.5	66.0	63.5

	12.00	12.12	12.24	12.36	12.48	13.00	13.12	13.24	13.36
	58.5	64.0	59.0	57.0	59.0	57.0	57.5	56.5	56.5
	60.5	66.5	61.5	61.5	61.5	61.0	61.0	59.5	59.0
	65.0	69.0	66.0	65.5	66.5	67.0	64.5	64.0	63.5

TABLE 3.1b (Continued).

Time.	13.48	14.00	14.12	14.24	14.36	14.48	15.00	15.12	15.24	15.36
L_{90}	60.0	60.0	56.0	56.5	58.0	63.0	60.5	57.5	56.0	58.0
L_{50}	63.5	62.5	61.0	60.5	61.0	66.0	63.5	62.5	62.5	62.0
L_{10}	67.0	65.5	65.5	65.5	65.0	69.0	66.0	67.0	67.5	66.0

TABLE 3.1b (Continued).

L_{90}	L_{50}	L_{10}	L_{90}	L_{50}	L_{10}
35.5	44.0	51.5	29.0	33.0	41.0
33.0	39.5	48.0	25.5	27.5	31.0
31.0	36.0	44.5	38.0	39.0	41.0
36.0	45.0	52.5	38.5	41.5	47.5
41.0	47.0	55.5	46.5	49.5	54.0
39.5	45.0	53.0	30.5	32.0	35.0
37.5	44.0	50.0	52.5	55.0	58.0
33.5	39.5	46.0	36.5	39.5	43.0
-	-	-	36.0	39.0	43.5
33.5	37.5	44.0	31.5	36.0	41.5
40.0	45.0	54.0	36.0	39.5	45.5
39.0	42.5	48.0	40.5	43.5	47.5
37.5	46.0	53.5	30.0	31.5	34.5
38.0	43.5	48.5	25.5	27.5	30.0
37.5	44.0	52.0	25.5	28.5	33.5
32.0	38.5	46.5	31.0	35.5	40.0
35.0	38.5	44.5	32.5	37.0	43.0
31.5	41.0	49.0	28.5	32.0	38.5
41.0	46.0	52.5	31.5	36.0	42.0
38.0	46.0	53.5	32.5	36.0	41.0

Station No 1. Station No 2.

TABLE 3.2a DUMBARTON HEALTH CENTRE (Various locations in waiting areas).

L_{90}	L_{50}	L_{10}	L_{90}	L_{50}	L_{10}
30.5	32.5	36.5	29.5	35.0	42.5
35.5	36.0	37.0	30.5	34.5	31.0
36.5	43.0	51.0	27.0	32.0	40.0
33.5	36.0	38.5	25.0	27.0	31.5
36.5	39.5	43.0	29.5	33.0	44.0
39.0	41.5	46.0	31.5	34.5	37.0
35.0	37.5	40.5	34.0	38.5	46.5
38.5	39.5	41.0	31.0	33.5	36.0
35.5	37.1	40.5	32.5	34.0	35.0
31.5	34.5	40.0	28.5	31.0	33.5
40.0	44.5	49.5	31.0	34.5	44.0
40.0	43.5	49.5	28.5	31.5	44.5
28.0	32.0	38.5	28.5	32.0	38.5
-	-	-	30.0	36.0	42.5
30.0	33.0	37.0	23.5	26.0	28.5
31.0	35.0	39.5	28.0	32.0	38.5
37.5	40.5	46.5	30.5	32.0	35.0
34.0	40.5	47.5	30.0	33.5	40.5
35.5	37.0	40.0	31.5	34.5	38.5
38.0	40.5	43.0	32.5	35.0	37.5

Station No 3.　　　　Station No 4.

TABLE 3.2a (Continued).

L_{90}	L_{50}	L_{10}	L_{90}	L_{50}	L_{10}
29.5	33.5	41.5	33.0	38.0	47.0
32.5	37.5	44.5	30.5	34.0	39.5
23.0	25.5	31.5	30.0	32.0	35.0
23.5	26.5	30.0	32.5	36.5	46.0
29.0	31.5	35.5	31.5	36.0	43.0
30.5	33.5	38.5	32.0	39.5	43.0
34.0	38.0	43.5	34.0	38.5	44.0
27.0	30.0	35.5	30.0	35.0	42.5
31.5	34.0	37.5	33.0	36.0	41.5
27.5	30.0	42.5	28.0	32.0	39.0
33.5	39.0	47.0	35.0	39.5	45.0
28.5	31.0	34.5	31.0	35.0	42.0
34.0	42.0	49.0	26.0	29.5	35.0
26.0	28.5	31.5	26.0	30.0	37.0
20.5	23.0	25.0	24.5	27.5	34.0
27.0	29.5	32.5	31.0	36.0	45.5
27.5	29.0	31.5	26.5	33.0	40.0
30.5	32.5	36.5	35.5	40.5	45.5
31.0	33.5	36.5	32.0	36.0	46.0
28.0	30.0	32.5	33.5	37.0	42.0
Station No 5.			Station No 6.		

TABLE 3.2a (Continued).

L_{90}	L_{50}	L_{10}	L_{90}	L_{50}	L_{10}
25.0	27.0	31.5	27.0	30.0	34.0
23.5	27.5	35.5	25.5	27.5	31.5
23.0	24.0	26.0	25.5	28.0	31.0
25.5	26.5	29.0	28.0	30.0	33.0
26.5	29.5	31.5	31.5	34.0	38.0
27.5	30.5	33.5	42.0	45.0	48.5
31.0	33.5	40.0	38.5	41.0	45.5
29.5	32.0	33.5	36.0	38.0	41.0
32.5	35.0	41.0	38.0	40.0	42.0
33.5	37.0	45.0	31.0	34.5	40.0
34.0	36.5	40.0	34.0	38.5	43.0
33.0	35.0	37.5	43.0	45.0	47.5
23.0	25.5	27.0	33.0	34.0	35.5
30.5	33.5	38.5	28.0	29.5	32.5
23.5	26.0	29.0	28.0	30.0	33.5
26.0	29.5	34.5	31.0	34.5	40.0
27.5	30.5	35.5	30.0	32.0	37.0
23.0	26.5	32.0	27.5	31.5	37.0
26.5	29.5	34.0	32.5	34.5	37.0
28.0	30.0	34.5	28.5	31.0	34.0
Station No 1A			Station No 2A		

TABLE 3.2b DUMBARTON HEALTH CENTRE (Various locations in consulting and social workers' rooms).

L_{90}	L_{50}	L_{10}
23.0	25.0	27.0
23.0	25.0	29.5
23.0	25.0	27.5
23.0	24.5	28.5
27.5	30.0	33.0
29.0	30.5	35.0
33.5	35.0	38.0
27.0	29.5	37.5
33.0	34.5	37.0
30.5	33.5	37.5
32.5	35.0	47.5
43.5	48.0	51.5
28.0	29.5	32.0
35.5	37.5	39.5
23.5	26.5	30.0
30.0	32.0	36.0
30.5	33.0	36.5
25.5	28.0	31.0
33.0	36.0	39.0
30.5	32.0	34.5

Station No 3A

L_{90}	L_{50}	L_{10}
23.0	25.0	27.5
21.0	23.5	26.5
23.0	24.0	26.0
23.0	25.5	27.0
29.0	30.5	38.0
27.5	30.0	41.0
32.5	37.5	42.5
28.0	32.0	37.5
31.0	33.5	30.0
26.0	29.0	45.0
33.0	36.0	39.5
28.0	30.5	32.5
25.5	28.0	37.5
25.0	26.5	29.5
23.5	27.5	35.0
29.5	32.0	34.5
28.5	31.0	33.5
30.5	33.5	37.5
35.5	37.5	41.5
29.5	36.5	43.5

Station No 4A

TABLE 3.2b (Continued).

L_{90}	L_{50}	L_{10}	L_{90}	L_{50}	L_{10}
24.5	26.5	29.5	25.5	27.0	29.0
23.5	26.5	37.0	25.5	27.0	29.5
23.0	25.0	28.5	25.5	27.5	30.0
23.5	26.0	28.5	27.5	29.5	32.5
31.5	33.0	35.5	29.0	30.5	34.5
34.0	36.0	46.0	28.5	30.0	33.5
29.0	31.5	41.5	31.0	33.0	35.5
26.5	29.0	47.0	26.0	27.0	28.5
33.0	34.0	36.5	35.0	32.0	34.5
25.0	26.5	29.0	28.0	30.5	32.5
35.5	38.5	41.5	29.0	31.5	34.0
29.0	31.5	35.0	28.0	29.5	32.0
25.5	26.5	29.5	25.5	26.5	30.0
23.0	24.5	27.5	25.5	28.0	29.5
23.0	24.0	26.0	24.5	27.0	31.0
28.0	30.0	33.5	25.5	26.5	29.5
24.5	27.0	34.0	25.0	26.5	32.0
29.0	31.5	34.5	33.0	34.0	37.0
33.0	34.5	37.0	30.5	33.0	47.0
33.0	35.5	39.0	33.0	35.5	37.5
Station No 5A			Station No 6A		

TABLE 3.2b (Continued).

APPENDIX IV CONSTRUCTIONAL DETAILS.

N.B. All drawings are contained in the pocket inside the rear outer cover.

PAISLEY SOUND TEST MOCK-UP: CLASP MK 5 - DESCRIPTION OF WORK TO GROUND FLOOR ROOMS FOR SUSPENDED CEILING AND INTERCOMMUNICATING DOOR TESTS.

For test No 1.

Remove p.v.c. sheeting and screed as far back from partitions as first welded joint. Also coved skirting as necessary.

Leave sub-floor suitable suitable to take 3mm minimum Laytex Screed overlaid with 2mm thermoplastic tile 'A.V.' Range. To be laid by Messrs. Dunlop Semtex. Provide Laytex fillet (or similar protection) at junction of 2 floor levels. Scribed hardwood bead, set in mastic over full height of partition between partition and external door frame.

Fix Dunlop Semtex hospital coved skirting as before, to relaid floor areas. Disconnect temporarily surface mounted light fittings. Remove existing ceiling tiles, leaving suspension system intact if possible. Remove existing ceiling tiles, leaving suspension system intact if possible. Remove existing plasterboard plenum barrier. (Tiles and existing plenum barrier will not be required for re-use.) Lay 50mm insulation quilt and insert new Minaboard tiles.

For test No 2.

Disconnect light fittings. Remove ceiling tiles and insulation adjacent to partition. Dismantle suspension system in same area. Fix plasterboard plenum barrier (specification to be as Technical Bulletin No. 25 and fixing as drawing No. 2 - One only 50 x 50mm angle at head and foot. Ensure no joint occurs over length of future door opening). Replace suspension members, tiles and insulation, ensuring continuity of insulation over ceiling and up plenum barrier. Re-locate light fittings.

For test No. 3.

Cut back skirting at 600mm and 900mm wide partition panels. Remove any ceiling perimeter trim fixings over this run of partition. Prise out lockrod between panels and carefully remove panels and stud. (Panels and stud to be replaced later.) Remove ceiling tiles adjacent to partition at removed panels. Cut out top and bottom track channels where panels removed. Leave plenum barrier intact. Re-arrange partition braces as necessary to maintain rigidity of top channel. Locate new partition casings. Include cut and patch to floor where casing fixing brackets occur.

Lay flooring as before in partition openings now formed. Instal CLASP door set as indicated on drawing Nos. 3A and 3B and CLASP standards drawings, including bracing support at head. Include plaster scrim at junction of door head with plasterboard plenum barrier. Return skirting into door ingo and make good adjacent to door frame where cut back to remove panels.

Fix ceiling trim at new ingo and insert tiles cut to suit. Ensure continuity of insulation quilt is maintained.

For test No. 4.

Remove skirting at ingo. Take down ceiling tiles adjacent to door to allow an additional CLASP door frame and hardwood sub-frame to be included. Details as indicated on drawings Nos. 4A and 4B. Include bracing support for new frame. Replace standard door leaf with $\frac{1}{2}$ hour fire door as indicated. Replace ceiling tiles ensuring insulation correctly located as before.

For test No. 5.

Hang second $\frac{1}{2}$ hour fire door with all door sealing arrangements as first $\frac{1}{2}$ hour door. Insert single special built-up panel in fanlight of second door set on the outside face. See Drawings Nos. 5A and 5B.

For test No. 6.

Remove single special built-up panel from fanlight of second door set and leave vacant. Line this panel on the plasterboard side with sheet lead approximately 1.6mm thick and exchange same with the outside fanlight panel on the first $\frac{1}{2}$ hour door side. Remove first and second $\frac{1}{2}$ hour fire doors each with 1 pair hinges and replace with Muirhead's 1 hour fire door mounted on $1\frac{1}{2}$ pair special steel hinges. Fit a set of Neoprene seals as indicated on Drawing No. 6 transferred from one of the $\frac{1}{2}$ hour fire doors.

Note - Latch set and level handles to be fitted to all door leaves.

For test No. 7.

Disconnect light fittings. Take down entire suspended ceiling system except perimeter trim. Remove perimeter trim fixings to door frames and partition casings. Remove plenum barrier, door frames and partition casings. Cut out section of flooring laid prior to Test No. 3 and re-locate track channel sections previously removed (timber plate to bolt replaced sections to existing). Re-locate 600mm and 900mm panels and stud with new lockrods. Fix perimeter trim back to panels. Include re-fixing of partition braces after removal of door frames and re-location of panels. Make good skirting (and floor screed if necessary). Fix 'Asbestolux' planks to rigid suspension system, see Drawing No 7. Include insulation and light fitting location as before. Re-use bulkhead insulation over partition as indicated to give continuity to quilt.

APPENDIX V INSTRUMENTATION AND DETAILS OF MEASUREMENT PROCEDURES.

N.B. Unless otherwise stated, type numbers given in brackets apply to equipment supplied by Bruel and Kjaer.

Va. Noise climate analysis.

A twin channel Revox recorder was used for the semi-permanent installation at the Woodside health centre. This recorder was fitted with a standard form of programmable time switch.

An external type microphone installation was fitted on a temporary roof mast. The internal microphone (4133) was powered by an independant supply unit (2801).

A Nagra 4B tape recorder was coupled to a portable sound level meter (2203), for all noise recordings in the Dumbarton health centre.

Tape recordings were subsequently analysed by means of an audio frequency spectrometer (2112), used in conjunction with a graphic level recorder (2305) and statistical distribution analyser (4420).

Vb. Sound insulation measurements.

The procedure adopted was to position matched microphones, type 4133 on either side of the partition. A microphone selector unit (4408) was employed to feed alternative signal levels to the audio spectrometer and graphic level recorder.

Three microphone positions were used on the noise input side of the partition and five on the receiving side. The positions were chosen a) to be clear of direct radiation from the loudspeakers and b) to be a minimum of 4 feet from any wall surface.

The noise input was obtained from a random noise generator (1402) and fed through a band-pass filter set (1612) and twin channel amplifier to two loudspeakers, each with a power capacity of 40 watts. The loudspeakers were pointing away from the test partition and positioned approximately 4 feet from opposite corners of the source room.

Vc. Reverberation measurements.

A starting pistol was used as a noise source. Five recordings were made at random positions in each room.

The Nagra recorder was used for all tape recordings and the tape was subsequently analysed at either octave or 1/3 octave frequency bands, using equipment described in previous sections.

NOTES

1. A Framework for Government Research and Development. H.M.S.O. Report Cmnd. 4814. 1971.

2. The origin of this method of construction is described by the Ministry of Education in The Story of CLASP. Building Bulletin 19. H.M.S.O. 1961.

3. Department of Health and Social Security. Health Centres - A Design Guide. H.M.S.O. 1970.

4. Ruth Cannock, Health Centre Handbook. London Borough of Newham/ Medical Architecture Research Unit, Northern Polytechnic. 1973.

5. Scottish Home and Health Department, Design Guide - Health Centres in Scotland. H.M.S.O. 1974.

6. Symposium No 12, The Control of Noise, National Physical Laboratory. H.M.S.O. 1962, p. 359.

7. E. Rowlands, Noise in Hospitals: Criteria and Masking Sounds. University College Environmental Research Group. London. 1971.

8. Anita B. Lawrence, Architectural Acoustics, Applied Science Publishers Ltd. London 1970, pp. 92-97.

9. Noise and Vibration Control, edited by L.L. Beranek, McGraw-Hill, New York 1971, pp. 586-589.

10. W.J. Cavanaugh, W.R. Farrel, P.W. Hirtle and B.G. Watters, Speech Privacy in Buildings. Journal of the Acoustical Society of America, Vol 34. 1962, pp 480-492.

11. R.W. Young, Revision of the Speech-Privacy Calculation, Journal of the Acoustical Society of America. Vol 38. 1965, pp 524-530.

12. Health centres visited in Scotland were located at Crieff, Perths., Livingston, West Lothian and Woodside, Glasgow.

13. Health Centres visited in England were at Mansfield, Arnold and Worksop (all of CLASP construction and located in Nottinghamshire), together with those at St. James St.,Higham Park and Hamsworth Ave. (of traditional construction and located within Greater London).

14 The building listed in notes 10 and 11 were selected by the Scottish Development Department, as a representative group for the purpose of the acoustic study. A preliminary survey form was also compiled in cooperation with the S.D.D., as a basis for discussion with the administrative officials.

15. This was a turning point for the direction of the research. A private communication from the CLASP Research and Development group had revealed that the sound insulation performance in the field of the Mk 4 partition could be as low as 33 dB. Antagonists of the CLASP system could point to this as a critical deficiency despite the counter advantage of speed of construction.

16. The design of this building implemented the survey findings reported in Hospital Planning Note 6 - Organisation and Design of Out-Patient Departments (commissioned by the S.H.H.D.). H.M.S.O. 1967.

17 Standard dictation tape. Pitman Shorthand Speed Development. Tape 4 (Red Leader).

18. Cavanaugh et al. op. cit. p. 477.

19. This building was constructed with the CLASP Mk 4B system. The open plan form was similar in character to the health centres previously visited in Nottinghamshire. At Dumbarton standard CLASP door-sets had been specified for communicating doors by the job architects. As the building neared completion the doctors, as the potential occupants, expressed strong dissatisfaction with the degree of speech privacy provided. Advice was sought from the S.D.D. and remedial measures suggested involved fitting additional CLASP door-sets and special seals. Field tests were carried out, after these remedial measures. Subsequent unsolicited comments by the doctors indicated a high level of satisfaction (see also following report on field trials, in the same building and the subsequent analysis in Chapter VII).

20. A similar conclusion is reported by Warnock, Acoustical Privacy in the Landscaped Office. Journal of the Acoustical Society of America. Vol 53. No 6. 1973, p. 1536.

21. Young, op. cit.

22. Cavanaugh et al, op cit.

23. Building types listed in the survey report included commercial offices, hospitals, dormitories and motels.

24. R.W. Young. Single Number Criteria for Room Noise. J. Acoust. Soc. Am. Vol 36 pp. 289-295. 1964.

25. D.M. Harman, The Role of the dBA. Applied Acoustics (2). pp. 101-109. 1969.

26. G.M. Jackson, G. Parkes and H.G. Leventhall. A Computor Study of the Relationship Between Noise Rating Assessment and dBA Levels. Applied Acoustics (5). pp. 191-204. 1971.

27. Wilson Committee on the Problem of Noise, Noise - Final Report H.M.S.O. Cmnd 2056. Appendix II p. 154. 1963.

28. F.J. Langdon and W.E. Scholes. The Traffic Noise Index: A Method of Controlling Noise Nuisance. Building Research Station. CP Ac3. 1968.

29. D.W Robinson, Towards a Unified System of Noise Assessment. J. Sound & Vibration. Vol 14. 1971.

30. P.H. Parkin, H.J. Purkis and W.E. Scholes. Field Measurements of Sound Insulation Between Dwellings. National Build. Studies Research Paper No 33. H.M.S.O. 1960.

31. O. Brandt. European Experience with Sound - Insulation Requirements. J. Acoust. Soc. Am. Vol 36. p. 719. 1964.

32. T.D. Northwood. Sound Insulation and the Apartment Dweller. J. Acoust. Soc. Am. Vol 36. p. 725-728. 1964.

33. Rademacher, H.J. Subjective Assessment of Sound Insulation Investigated by Electrically Reproduced Sound Insulation Curves. Acustica. 5, 19. 1955.

34. Cavanaugh et al, op. cit. p. 482.

35. Warnock, op. cit. p. 1536.

36. H.D. Parbrook. The Practice of Sound Control, Noise Measurement and Control. Ed. P. Lord and F.L. Thomas. 1963.

37. A. Bains. Acoustic Factors. Architects Journal Handbook: Office Building. Section 8. Environment. Information Sheet, Environment 1. p. 1330.

38. A specific reference absorption is not quoted by Bains. Instead a procedure for adjusting the sound pressure level relative to the sound power level is given. This procedural variation, coupled with the marked differences in the speech nomograms, makes for scepticism in the mind of any designer who may wish to use this form of predictive method. Neither method allows for a change of shape in the nomogram, which may be caused by the variation of room absorption.

39. C.E. Williams and K.N. Stevens. Emotions and Speech: Some Acoustical Correlates. Jour, Acoust. Soc. Am. Vol 52. No 4 (Part 2) 1972, p. 1245.

40. R. Pirn. Acoustical Variables in Open Planning. J. Acoust. Soc. Am. 49. No 5 (Part 1). 1971. 'The really significant observation is that a change of 0.2 to 0.3 in the Articulation Index can completely alter the balance from a condition of privacy to one of communication and vice versa.'

41. A detailed critique of articulation index theory is also provided by J. Flanagan and H. Levitt. Speech Interference from Community Noise, Conf. Noise as a Public Health Hazard. Amer. Speech & Hearing Assn. 1969.

42. The significant departure is that in the following experiments the subject is required to assess privacy, in relation to various speech passages, instead of random syllables.

43. The graph illustrated is the line of best fit. The measured noise spectrum as presented to the subject (i.e. as modified by the room acoustics) was within $\pm$ 2 dB of this curve.

44. For the purpose of calibration i.e. analysis of levels as presented to the subject, the monitoring microphone was placed within the subject zone and an average of three readings taken for each 1/3 octave band.

45. The intelligence quotient ratings of subjects was not known, but was collectively almost certainly above the average for all patients.

46. The intruding speech level may therefore be considered in terms of permissible signal to noise ratio. The results for sub-group B (representing occupants) were slightly more consistent and are taken as the basis for the predictive method of Chapter VI.

47. Rowlands et al, op. cit.

48. N.M. Orr. Department of Clinical Physics and Bio-Engineering, Western Regional Hospital Board. - Private communication.

49. The frequency of recording was determined by the time taken by the observer to set up the sound level meter and the recorder.

50. The first 40 seconds of the recording was omitted to avoid distortions of level due to warm-up time and switching noises.

51. A number of spot recordings, both internal and external, indicated that the noise climate should be similar to that of the Dumbarton Health Centre.

52. Values shown in these tables are based upon electro-graphical analysis of tape recordings to determine the dBA L_{10}, L_{50} and L_{90} levels. The L_{50} level was then used for routine statistical analysis.

53. The first of these measuring stations is in a waiting area, the second in a consulting room.

54. Noise and Vibration Control, edited by L.L. Beranek. PP. 588-594.

55. R.A. Waller. Office Acoustics - Effect of Background Noise, Applied Acoustics (2) 1969, pp. 128-130.

56. Cost comparison based on (a) estimate for cost of special door, seals and frame by S.D.D. quantity surveyors and (b) tender figure for a suitable electronic installation, against a detailed specification prepared by the author, submitted by a specialist firm.

57. This conclusion is at variance with that quoted by Waller. op. cit. p. 129.

58. The most significant structural change was from timber to concrete intermediate floor construction.

59. The CLASP test building at Paisley Royal Infirmary bears a superficial resemblance to the test chambers described in Report No AMA-1-II prepared for the Acoustical Materials Association by Geiger and Hamme. Vertical flanking transmission paths were present at Paisley, however, which would be minimized in the test facility described in that report.

60. Various tests were carried out on brick walls, with and without doors, at the Woodside Health Centre, in the preliminary stages of the research.

61. Lockwood A.J. and Pedder-Smith, D.W. Variety Reduction in Doormaking. Building Research Station, Current Paper 32/69. 1969. p.6. 'It would seem that a more likely potential source of reduced prices to the client would be found in a more judicious selection of door models to suit specific requirements.'

62. Preliminary tests were also carried out in a school extension at Lanark but proved unsatisfactory due to relatively heavy fixtures on the partition.

63. In general, designations for test results follow definitions laid down by the International Standards Organisation (ISO).

64. The standard Neoprene gasket was found to be unsatisfactory, as it does not follow the door contour throughout, if the door is slightly warped. In these circumstances the seal is inefficient and the door difficult to close.

65. The manufacturer's recommendations favoured the detail shown in 4e and a complicated set of instructions is provided for the operative.

66. A further objection to 4e which arose at Paisley (and which did not arise with detail 4d as used at Falkirk) is that the operative instinctively positions the aluminium housing parallel to the edge of the door jamb, instead of following the door contour. The reason given is that of appearance.

67. This result was disappointing, even though the asbestos plank ceiling was considerably heavier than the fibreboard version. The asbestos ceiling also increased the reverberation time of the room considerably (see Fig 5.7).

68. P.H. Parkin, H.J. Purkis and W.E. Scholes, op. cit. pp. 73-86.

69. International Standards Organisation. ISO/R-717-1968(E). Rating of Sound Insulation for Dwellings. British Standards Inst. 1968.

70. American Society for Testing and Materials. Proposed Classification for Determination of Sound Transmission Class. Report No RM 14-2. Philadelphia. 1966.

71. A first proposal ISO 140 Part III (December 1973) has been put out as a circular for comment. In this document a procedure is described for the measurement but not the estimation of flanking transmission.

72. The basic Sabine's formula is used as the average absorption coefficient $\leqq$ 0.2.

73. J.E.R. Constable. The Transmission of Sound in a Building by Indirect Paths. Proc. Phys. Soc. Vol 50. 1938. p.368-373. See also F. Ingerslev, Acoustics in Modern Building Practice, 1952. pp. 223-224. Although this method of estimating flanking transmission was derived from measurements in buildings of traditional construction, the magnitude of the allowance appears to be similar for lightweight partitions.

74. The health centre at Dumbarton and the outpatients' department are examples of this form of plan.

75. The health centre at Woodside (an earlier building) represents this alternative form.

76. This is the condition simulated by the laboratory experiments.

77. It may be argued that the outpatients' department operates on a tighter time schedule than the health centre; furthermore a nurse may be in attendance upon the patient. If this is so then lower standards may be acceptable. Also the patient is less likely to meet an acquaintance in the hospital.

78. A.F.E. Wise. Building in Noisy Areas - Interaction of Acoustic and Thermal Design. Building Research Station Current Paper. 43/69. 1969, p. 4.

79. These conditions were inherent in the outpatients' department at Falkirk. The remedial measure to be adopted involves fitting external, extending, fabric sunblinds.

80. A considerable effort has been devoted in recent years by the Building Research Establishment to the production of suitable design aids for the thermal environment - see for example, N.O. Millbank, A New Approach to Predicting the Thermal Environment in Buildings at the Early Design Stage. B.R.S. C.P. 2/74.

81. The experimenter could also observe and verify the instrument setting through the observation window.

82. In theory, a quadrophonic technique might also be employed; this would simulate back reflections and flanking effects, in addition to the partition as a primary source. The same technique could also be used to localize the source in relation to the subject, thus reproducing the position of a door or similar element in the partition.

In practice it is doubtful if any effective increase in the accuracy of the experiment would follow; assuming that the receiving room which is being simulated is small and heavily damped. The extra effort could be worthwhile if the receiving room is larger and more reverberant.

BIBLIOGRAPHY

ACOUSTICAL MATERIALS ASSOCIATION. Sound Transmission over Partitions Erected to Suspended Acoustical Ceilings. Report No AMA-I-II. New York. 1961.

ACOUSTICAL MATERIALS ASSOCIATION. Standardized Mountings for Ceiling Sound Transmission by the Two-Room Method. Report No AMA-I-II. New York. 1963.

ACOUSTICAL MATERIALS ASSOCIATION. Ceiling Sound Transmission Test by the Two-Room Method. Report No AMA-I-II. New York. 1967.

ACOUSTICAL MATERIALS ASSOCIATION. Sound Transmission over Partitions Erected to Suspended Acoustical Ceilings. Report No AMA-I-IV. New York. 1968.

AMERICAN SOCIETY FOR TESTING AND MATERIALS. Proposed Classification for Determination of Sound Transmission Class. Report No RM 14-2. Philadelphia. 1966.

AMERICAN SOCIETY FOR TESTING AND MATERIALS. Recommended Practice for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions. Report No E90-70. Philadelphia. 1970.

AMERICAN SOCIETY FOR TESTING AND MATERIALS. Installation of Fixed Partitions of Light Frame Type for the Purpose of Conserving their Sound Insulation Efficiency. Report No E497-73T. Philadelphia. 1973.

AMERICAN SOCIETY FOR TESTING AND MATERIALS. Measurement of Airborne Sound Insulation in Buildings. Report No E336-71. Philadelphia. 1971.

AMERICAN SOCIETY FOR TESTING AND MATERIALS. Sound Transmission Class. Report No E90-61T. Philadelphia. 1961.

BAINS A. Acoustic Factors. Architects Journal Handbook: Office Building. Section 8. Environment. Information Sheet, Environment 1. Nov 1973.

BAZLEY, E.N. The Airborne Sound Insulation of Partitions. H.M.S.O. London. 1966.

BERANEK, L.L. Acoustic Impedance of Commercial Materials and the Performance of Rectangular Rooms with One Treated Surface. Journal of the Acoustical Society of America. 12. 14-23. 1940.

BERANEK, L.L. Design of Speech Systems. Proceedings of I.R.E., 35, 880-890. 1947.

BERANEK, L.L. Acoustics. McGraw-Hill Book Co Inc. New York. 1954.

BERANEK, L.L. Revised criteria for Noise in Buildings. Noise Control, 3, 19-27. 1957.

BERANEK, L.L. Criteria for Office Quieting Based on Questionnaire Rating Studies. Journal of the Acoustical Society of America. 28, 833. 1965.

BERANEK, L.L. Noise and Vibration Control. McGraw-Hill Book Co Inc. New York. 1971.

BOLT, R.H. & NEWMAN, R.B. Architectural Acoustics. Architectural Record, April, June, September and November 1950.

BOTTOM, C.G. & CROOME, D.J. Road Traffic Noise - Its Nuisance Value. Applied Acoustics. Vol 2. No 279. 1969.

BRITISH GYPSUM LIMITED. Sound Attenuation of Plasterboard and Gyptone Tile Ceiling Linings. British Gypsum Information Bulletin. 2nd Series. No 8. 1972.

BRITISH STANDARDS INSTITUTION. Recommendations for Field and Laboratory Measurement of Airborne and Impact Sound Transmission in Buildings. B.S.I. 2750:1956.

BRITISH STANDARDS INSTITUTION. Method for the Measurement of Sound Absorption Coefficients (ISO) in a Reverberation Room. B.S.I. 3638:1963.

BRITISH STANDARDS INSTITUTION. Method for Calculating Loudness. B.S.I. 4198:1967.

BRITISH STANDARDS INSTITUTION. Sound Insulation and Noise Reduction B.S.I. CP3: Ch III: Part 2: 1972.

BRITISH STANDARDS INSTITUTION. Specification for a Precision Sound Level Meter. B.S.I. 4197:1967.

BROADBENT, G.H. Design Methods in Architecture. Architects Journal. 144. 1966.

BROCH, J.T. Acoustic Noise Measurements. Brüel and Kjaer. Copenhagen. 1971.

BROWN, S. & KEITH, A. Acoustic Faults in Contemporary Architecture. New Scientist. 14. 292. 1959.

BRUEL & KJAER. Technical Review. Nos 3, 1958; 1, 1959; 2, 1959; 2, 1960; 4, 1960; 2, 1961; 4, 1962; 1, 1964; 4, 1964; 1, 1965.

BUILDING PERFORMANCE RESEARCH UNIT. Building Performance. Applied Science Publishers Limited. 1972.

BUILDING RESEARCH STATION. Noise and Buildings. B.R.S. Digest 38. 2nd Series. 1963.

BUILDING RESEARCH STATION. Sound Insulation and New Forms of Construction. B.R.S. Digest 96. 2nd Series. 1968

BUILDING RESEARCH STATION. Sound Insulation of Traditional Dwellings - 1. B.R.S. Digest 102. 1969.

BUILDING RESEARCH STATION. Sound Insulation of Traditional Dwellings - 2. B.R.S. Digest 103. 1969

BUILDING RESEARCH STATION. Insulation Against External Noise - 1. B.R.S. Digest 128. 1971.

BUILDING RESEARCH STATION. Insulation Against External Noise - 2. B.R.S. Digest 129. 1971.

BUILDING RESEARCH STATION. Motorway Noise and Dwellings. B.R.S. Digest 135. 1971.

BUILDING RESEARCH STATION. Sound Insulation and the Scottish Building Regulations. B.R.S. Seminar Notes 286/71; 315/72; 288/71; 289/71. 1972.

CANBY, E.T. Implications of Low-Noise Background. Sound Eng Mag. 3, No 6. 1969.

CANNOCK, R. Health Centre Handbook. London Borough of Newham. Medical Architecture Research Unit, Northern Polytechnic.1973.

CANNOCK, R. Health Centres - Reception, Waiting and Patient Call. Department of Health and Social Security/H.M.S.O. 1973.

CAVANAUGH, W.J., FARRELL, W.R., HIRTLE, P.W. & WATTERS, B.G. Speech Privacy in Buildings. Journal of the Acoustical Society of America. Vol 34. No 4. 1962.

CLARK, D.M. Subjective Study of the Sound-Transmission Class System for Rating Building Partitions. Journal of the Acoustical Society of America. Vol 47, No 3 (Part 1). 676-682. 1970.

CORMACK, J.J.C. When is a Health Centre not a Health Centre? - Establishment and Early Operation of the Ladywell Medical Centre, Corstorphine, Edinburgh. The Practitioner. Vol 211. December 1973.

COX, D.R. Planning of Experiments. John Wiley & Sons Inc. New York. 1958.

CUIN, D.E. Sound Insulation and Modern Partition Design. Insulation. London 1971.

DAVIES, H.G. Noise Propagation in Corridors. Journal of the Acoustical Society of America. Vol 53, No 5. May 1973.

DAY, B.F., FORD, R.D. and LORD, P. Building Acoustics. Elsevier Publishing Co Limited. London. 1969.

DE BRUIJN, A. Influence of Diffusivity of the Transmission Loss of a Single-Leaf Wall. Journal of the Acoustical Society of America. Vol 47. No 3 (Part 1), 667-675. 1970.

DELANY, M.E., COPELAND, W.C. and PAYNE, R.C. Propagation of Traffic Noise in Typical Urban Situations. National Physical Laboratory. Acoustics Report No Ac 54. 1971.

DEPARTMENT OF THE ENVIRONMENT (HOUSING DEVELOPMENT DIRECTORATE). New Housing and Road Traffic Noise - a Design Guide for Architects. H.M.S.O. London. 1972.

DEPARTMENT OF HEALTH AND SOCIAL SECURITY. Health Centres - A Design Guide H.M.S.O. London. 1970.

DOWNIE, N.M. and HEATH, R.W. Basic Statistical Methods. 3rd Edition. Harper and Row Publishers. New York. 1970.

EDELMAN, S., WATERHOUSE, R.V. and LUNBACK, H.J. Sound Insulation of Wall and Floor Constructions. United States Department Of Commerce, National Bureau of Standards, Building Materials and Structures. Report No 144. Washington. 1955.

ERIKSSON, L.J. Practical Sound-Power-Level Measurements. Journal of the Acoustical Society of America. Vol 52. 149. 1972.

EVANS, E.J. and BAZLEY, E.N. Sound Absorbing Materials. H.M.S.O. London. 1960.

FARREL, W.R. Evaluation of the Effectiveness and Acceptability of Masking Noise for Providing Speech Privacy in Buildings. 60th Meeting of the Acoustical Society of America. Paper T7. 1960.

FISHER, R.A. and YATES, F. Statistical Tables (Sixth Edition). Longman. London. 1974.

FITZROY, D. Reverberation Formula which Seems to be More Accurate with Non-Uniform Distribution of Ansorption. Journal of the Acoustical Society of America. 31, 893-897. 1959.

FORD, R.D. and KERRY, G. The Sound Insulation of Partially Open Double Glazing. Applied Acoustics. 1973.

FRENCH, N.R. and STEINBERG, J.C. Factors Governing the Intelligibility of Speech Sounds. Journal of the Acoustical Society of America. 19, 90. 1947.

GOMPERTS, M.C. Sound Leaks, an Investigation into the Influence of Small Apertures and Narrow Slits on Sound Insulation. 1G-TNO. Rep 33. Delft. 1968.

GOSELE, K. Airborne Sound Insulation of Single Partitions and Ceilings. Acustica. 20. 334-342. 1968.

GRAY, P.G., CARTWRIGHT, A. and PARKIN, P.H. Noise in Three Groups of Flats with Different Floor Constructions. National Building Studies Res Paper No 27. H.M.S.O. 1958.

GREATER LONDON COUNCIL. Traffic Noise: Major Urban Roads. G.L.C. 7168-0311-9. 1970.

GRIFFITHS, I.D. and LANGDON, F.J. Subjective Response to Road Traffic Noise. Journal of Sound and Vibration. Vol 8, No 16. April 1968.

HAMME, R.N. Understanding Sound Transmission Loss of Lightweight Partitions. Noise Control. 6, 13-17. 1960.

HAMME, R.N. Laboratory Measurements of Sound Transmission Through Suspended Ceiling Systems. Journal of the Acoustical Society of America. 33, 1523-1530. 1961.

HAMME, R.N. and HUGGINS, D.N. The Problem of Acoustical Specifications for Office Landscape Ceilings. Journal of the Acoustical Society of America. Vol 52. No 120. 1972.

HARDY, A.C. and LEWIS, P.T. Reply to 'Window Insulation Against Traffic Noise'. Journal of Sound and Vibration. 20. No 1. 124. 1972.

HARMAN, D.M. The Role of the dB(A). Applied Acoustics. 2. 1969.

HEEBINK, T.B. and GRANTHAM, J.B. Field/Laboratory STC Ratings of Wood-Framed Partitions. Journal of Sound and Vibration. 5. No 10. 12-16. 1971.

HIGGINSON, R.F. A Study of Measuring Techniques for Airborne Sound Insulation in Buildings. Journal of Sound and Vibration. 21. No 4. 405-430. 1972.

HIGGINSON, R.F. Sound Insulation between Rooms having Resilient Linings on the Walls. Applied Acoustics. 3. 1970.

HILLIER, A.J. Acoustic Data - How to Use It. Insulation. 13. No 6. 262-266. 1969.

HUMPHREYS, H.R. and MELLUISH, D.J. Sound Insulation in Buildings. Cost and Performance of Walls and Floors. Department of the Environment. H.M.S.O. 1971.

INGERSLEV, F. and NIELSON, K. On the Transmission of Sound Through Small Apertures and Narrow Slits. Publ. No 1 Acoustical Laboratory of the Academy of Technical Science. Copenhagen. 1944.

INGERSLEV, F. Acoustics in Modern Building Practice. Architectural Press. London. 1952.

INTERNATIONAL STANDARDS ORGANISATION. ISO 140 Building Acoustics - Measurements of Sound Transmission. Part III. Field Measurements of Airborne Sound Transmission between Rooms. ISO/TC 43/SC 2 (Secretariat - 58). Brit. Standards Inst. 1973.

INTERNATIONAL STANDARDS ORGANISATION. ISO R140 Field and Laboratory Measurements of Airborne and Impact Sound Transmission. Brit. Standards Inst. 1960.

INTERNATIONAL STANDARDS ORGANISATION. ISO/R-717-1968(E). Rating of Sound Insulation for Dwellings. Brit. Standards Inst. 1968.

JACKSON, G.M. and LEVENTHALL, H.G. The Acoustics of Domestic Rooms. Applied Acoustics. 5. 1972.

JACKSON, G.M., PARKES, G. and LEVENTHALL, H.G. A Computor Study of the Relationship between Noise Rating Assessment and dB(A) Levels. Applied Acoustics. 5. 1972.

JAIN, R.K. and MULHOLLAND, K.A. A Databank of Sound Insulation Measurements. Applied Acoustics. 1973.

JOHNSON, D.R. and SAUNDERS, E.G. The Evaluation of Noise from Freely Flowing Road Traffic. Journal of Sound and Vibration. Vol 7. No 287. 1968.

KASTELEIJN, M.L. The Statistical Spread of Measured Airborne and Impact Sound Insulation in the Field. Journal of Sound and Vibration. 3(1). 36-45. 1966.

KEIGHLEY, E.C. The Determination of Acceptability Criteria for Office Noise. Journal of Sound and Vibration. Vol 4 (1), 73-87. 1966.

KEIGHLEY, E.C. Acceptability Criteria for Noise in Large Offices. Building Research Station Current Paper. CP 15/70. 1970.

KIHLMAN, T. Ljudtransmission genom springor (Sound Transmission Through Slits). Byggforskningen. Rapport 93. Stockholm. 1963.

KNUDSEN, V.O. and HARRIS, C.M. Acoustical Designing in Architecture. John Wiley and Sons Inc. New York. 1950.

KOSTEN, C.W. and VAN OS, G.J. Community Reaction Criteria for External Noises. National Physical Laboratory. Symposium No 12. 'The Control of Noise'. Paper F5. 1961.

KRYTER, K.D. and WILLIAMS, C.E. Masking of Speech by Aircraft Noise. Journal of the Acoustical Society of America. 39. 138-150. 1966.

KRYTER, K.D. The Effects of Noise on Man. Academic Press. New York. 1973.

KUTTRUFF, H. Room Acoustics. Applied Science Publishers Ltd. London. 1973.

LANE, R.N. and MIKESKA, E.E. Problems of Field Measurement of Transmission Loss as Illustrated by Data on Lightweight Partitions Used in Music Buildings. Journal of the Acoustical Society of America. 33. 1131-1139. 1961.

LANG, J. Differences between Acoustical Insulation Properties Measured in the Laboratory and Results of Measurements In-Situ. Applied Acoustics. 5. 1972.

LANGDON, F.J. The Design of Mechanised Offices. Architects Journal. 137. 943-7, 1081-6. 1963.

LANGDON, F.J. Modern Offices: A User Study. National Building Studies. Res. Paper No 41. H.M.S.O. London. 1965.

LANGDON, F.J. and SCHOLES, W.E. The Traffic Noise Index - a Method of Controlling Noise Nuisance. Building Research Station. Current Paper. CP 38/68.

LICKLIDER, J.C.R. Three Auditory Theories, Psychology: A Study of a Science edited by S. Koch. McGraw-Hill Book Co Inc. New York. 1959.

LOCKWOOD, A.J. and PEDDER-SMITH, D.W. Variety Reduction in Doormaking. Building Research Station. Current Paper 32/69. 1969.

LONEY, W. Effect of Cavity Absorption and Multiple Layers of Wallboard on the Sound Transmission Loss of Steel-Stud Partitions. Journal of the Acoustical Society of America. Vol 53. No 6. 1530-1534. June 1973.

LORD, P. Application of Simple Acoustic Principles to Low Cost Housing with a View to Reducing Loss of Comfort Due to Noise. Applied Acoustics. 3. 1970.

LORD, P and THOMAS, F.L. Noise Measurement and Control. Heywood & Co Limited. London. 1963.

MACKENZIE, R. Study of the Effect upon Sound Transmission of Absorption within the Cavity of a Timber Stud/Plasterboard Partition. Journal of the Acoustical Society of America. Vol 52. 119. 1972.

MAEKAWA, Z. Noise Reduction by Screens. Applied Acoustics. Vol 1. No 157. 1968.

MALING, Jr. G.C. and LANG, W.W. Single Number Noise Rating for One-Third Octave Band Sound Power Levels. Journal of the Acoustical Society of America. Vol 52. No 3 (Part 1). 1972.

MANN, L. Jr. Applied Engineering Statistics for Practicing Engineers. Barnes and Noble. New York. 1970.

MARINER, T. Critique of the Reverberent Room Method of Measuring Airborne Sound Transmission Loss. Journal of the Acoustical Society of America. 33. 1131-1139. 1961.

MARSH, J.A. The Airborne Sound Insulation of Glass: Part 1. Applied Acoustics. 4. 1971.

MARSH, J.A. The Airborne Sound Insulation of Glass: Part 2. Applied Acoustics. 4. 1971.

MILBANK, N.O. A New Approach to Predicting the Thermal Environment in Buildings at the Early Design Stage. Building Research Establishment. Current Paper. CP 2/74. 1974.

MILLER, L.N. A Sampling of New York City Traffic Noise. Noise Control. 6. 39-43. 1960.

MINISTRY OF EDUCATION. The Story of CLASP. Building Bulletin 19. H.M.S.O. 1961.

MINISTRY OF HEALTH. Noise Control. Hospital Design Note 4. H.M.S.O. London. 1966.

MINISTRY OF HEALTH. Buildings for General Medical Practice. H.M.S.O. London. 1967.

MOORE, J.E. Design for Noise Reduction. The Architectural Press. London. 1966.

MULHOLLAND, K.A. Method for Measuring the Sound Insulation of Facades: Factors to be Considered. Applied Acoustics. 4. No 4. 279-286. 1971.

MULHOLLAND, K.A. Sound Insulation Measurements on a Series of Double Plasterboard Panels with Various Infills. Applied Acoustics. 4. 1971.

NATIONAL BUILDING AGENCY & COLLEGE OF GENERAL PRACTITIONERS. Design Guide for Medical Group Practice Centres. Southern Publishing Co Ltd. Brighton. 1967.

NATIONAL BUREAU OF STANDARDS. Sound Isolation of Wall, Floor and Door Constructions. Nomograph 77. Washington. 1964.

NATIONAL PHYSICAL LABORATORY. The Control of Noise. Symposium No 12. H.M.S.O. 1962.

NILSSON, A.C. Reduction Index and Boundary Conditions for a Wall Between Two Rectangular Rooms. Part 1 Theoretical Results. Acustica 26. No 1. 1-18. 1972.

NILSSON, A.C. Reduction Index and Boundary Conditions for a Wall Between Two Rectangular Rooms. Part II Experimental Results. Acustica 26. No 1. 19-23. 1972.

NORTHWOOD, T.D. Sound Insulation Ratings and the New ASTM Sound Transmission Class. Journal of the Acoustical Society of America. 34. 493. 1962.

NORTHWOOD, T.D. Sound Insulation and the Apartment Dweller. Journal of the Acoustical Society of America. 36. 725. 1964.

OLSON, H.F. Acoustical Engineering. D. Van Nostrand Co Inc. Princeton, New Jersey. 1957.

OWENS-CORNING FIBERGLAS CORP. Solution to Noise Problems in Apartments and Hotels. Owens-Corning Fiberglas Corp. Toledo, Ohio. 1969.

ROWLANDS, E. Noise in Hospitals: Subjective and Objective Criteria. University College Environmental Research Group. 1968.

ROWLANDS, E. Noise in Hospitals: Criteria and Masking. University College Environmental Research Group. 1971.

ROYAL COMMISSION ON MEDICAL EDUCATION. Report Cmnd 3569. H.M.S.O. 1968.

RUCKER, A. and GLUCK, K. The Propagation and Suppression of Road Traffic Noise in Built up Areas. Strassenbau und Strassenverkehrstechnik Heft 32. (English Translation) B.R.S. Library Communication No 1314. 1964.

SADOWSKI, J. Influence of Building Design on the Acoustic Qualities of Partition Walls. Building Science. 4 No 3. 159-171 French. 1969.

SCHOLES, W.E. Traffic Noise Criteria. Applied Acoustics. Vol 3. No 1. 1970.

SCHOLES, W.E. and SALVIDGE, A.C. Statistical Analysis from a Sound Level Meter. Building Research Station. CP 15/73. 1973.

SCHOLES, W.E., SALVIDGE, A.C. and SARGENT, J.W. Field Performance of a Noise Barrier. Building Research Station Current Paper. CP 24371. Aug. 1971.

SCHOLES, W.E. and SARGENT, J.W. Designing Against Noise from Road Traffic. Building Research Station Current Paper. CP 20/71. 1971.

SCOTTISH DEVELOPMENT DEPARTMENT. Design Guide - Health Centres in Scotland. H.M.S.O. 1974.

SCOTTISH HOME AND HEALTH DEPARTMENT. Organisation and Design of Out-Patient Departments. Hospital Planning Note 6. H.M.S.O. 1967.

SEWELL, E.C. Sound Transmission Within Buildings. Physics Abstract 54344 Sept 1971. Insulation 15. No 1. 20-21. 1971.

SEWELL, E.C. and UTLEY, W.A. The Effect of Resilient Fillings on Direct and Flanking Sound Transmission with Cavity Masonry Walls. Building Research Establishment. PD 44/73. 1973.

SHARPE, B.H.S. and BEAUCHAMP, J.W. The Transmission Loss of Multi-Layer Structures. Building Research Station. CP/31/69. 1969.

SHEARER, K. Controlled Acoustics. Consulting Engineer. 33. No 5. 64-65. 1969.

SIEKMAN, W., YERGES, J.F. and YERGES, L.F. A simplified Field Sound Transmission Test. Journal of Sound and Vibration. 5. No 10. 17-21. 1971.

SMART, D.G. A New Charted System for the Specification of Structure-Borne Noise Control. Applied Acoustics. 5. 1972.

STATENS PLANVERK. (National Swedish Board of Urban Planning) Svensk Byggnorm 67 (Swedish Building Code 1967). Stockholn. 1967.

STEPHENSON, R.J. and VULCAN, G.H. Urban Planning Against Noise. Official Architecture and Planning. May 1967.

TOCCI, G.C. and DAVIES, H.G. Noise Propagation in Corridors. Journal Of the Acoustical Society of America. Vol. 52. 119. 1972.

TSEO, G.G. Estimating the Noise Reduction of Wall Structures of Enclosures. Journal of the Acoustical Society of America. Vol 52. No 6 (Part 1). 1972.

UNIVERSITY GRANTS COMMITTEE, DEPARTMENT OF EDUCATION AND SCIENCE. CLASP/JDP. The Development of a Building System for Higher Education. Building Bulletin No 45. H.M.S.O. 1970.

U.S. DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT. Authors BERENDT, R.D., WINZER, G.E. and BURROUGHS, C.B.) A Guide to Airborne, Impact and Structure Borne Noise. - Control in Multi-Family Dwellings. U.S. Dept. Housing and Urban Development. FT/TS-24. Washington. 1967.

U.S. GYPSUM COMPANY. Sound Control in Design. 1959.

UTLEY, W.A. Window Insulation Against Traffic Noise. Journal of Sound and Vibration. 20. No 1. 1972.

VAN DEN EIJK, J. Van Doorn-Ijzerman's New "Mass Law". Journal of Sound and Vibration. 3.1. 20-25. 1966.

VAN DEN EIJK, J. Sound Insulation Between Dwellings: Correction to 10.log S/A or to 10log T/0.5?. Applied Acoustics 5. 305-307. 1972.

WALLER, R.A. Economics of Sound Reduction in Buildings. Applied Acoustics. 1. 205-213. 1968.

WALLER R.A. Acoustics of Offices. Insulation. 13. No 2. 61-62. 1969.

WALLER, R.A. Office Acoustics - Effect of Background Noise. Applied Acoustics. 2. 1969.

WARNOCK, A.C.C. Acoustical Privacy in the Landscaped Office. Journal of the Acoustical Society of America. Vol 53. No 6. 1535-1543. 1973.

WEBSTER, J.C. Effects of Noise on Speech Intelligibility. Proceedings Conference of the Speech and Hearing Association. - Noise as a Public Hazard. Washington D.C. Feb 1969.

WILLIAMS, C.E. and STEVENS, K.N. Emotions and Speech: Some Acoustical Correlates. Journal of the Acoustical Society of America. Vol 52. No 4 (Part 2). 1972.

WESTERBERG, G. On the Sealing of Circular Holes in a Thick Wall for the Purpose of Sound Insulation. Applied Acoustics 4. 1971.

WILSON COMMITTEE. Final Report of the Committee on the Problem of Noise. Cmnd 2056. H.M.S.O. 1963.

WINZER, G.E. Noise Exposure Site Assessment Techniques. Journal of the Acoustical Society of America. 50. 84. 1971.

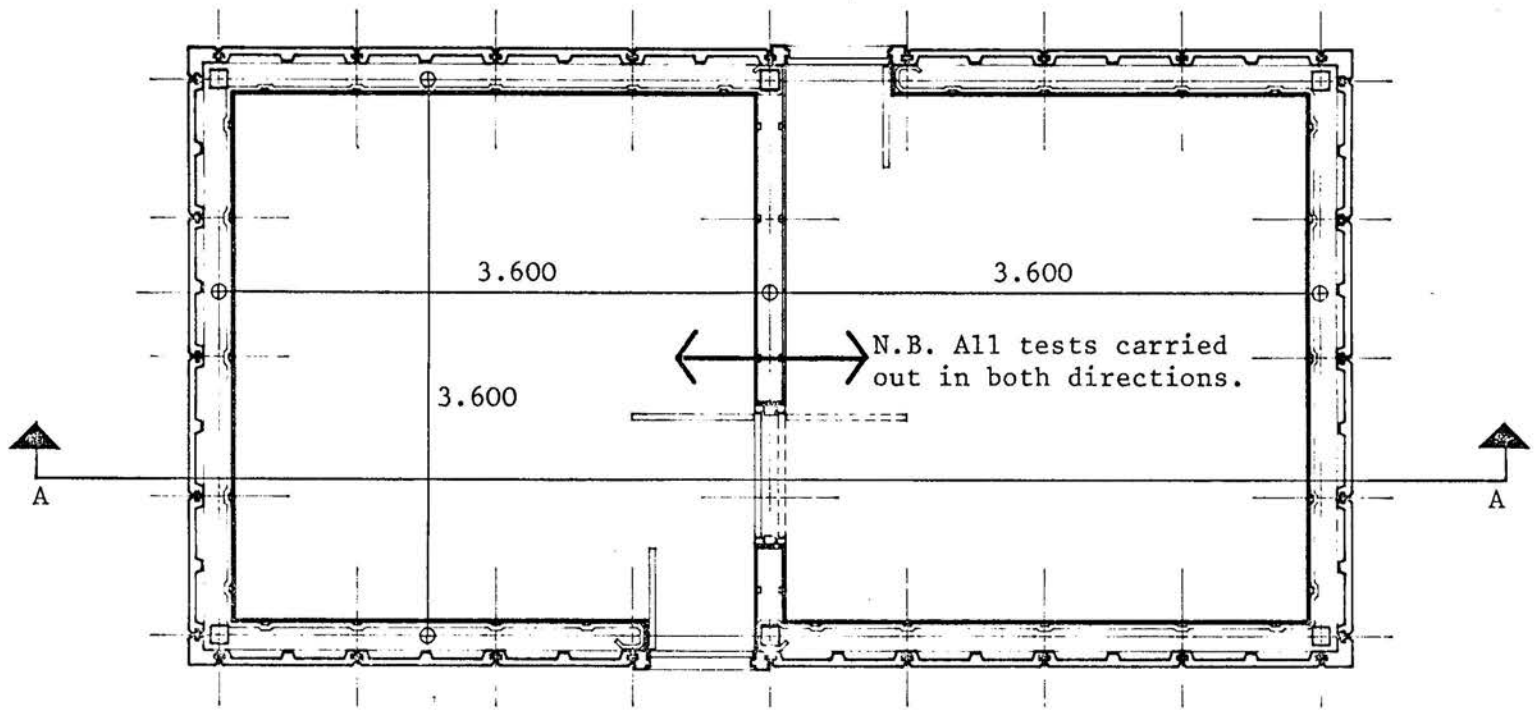
WISE, A.F.E. Buildings in Noisy Areas. Building Research Station. CP 43/69. 1969.

WOOLEY, R.M. Sound Insulation of Windows. Building Research Station. Design Paper No 64. 1967.

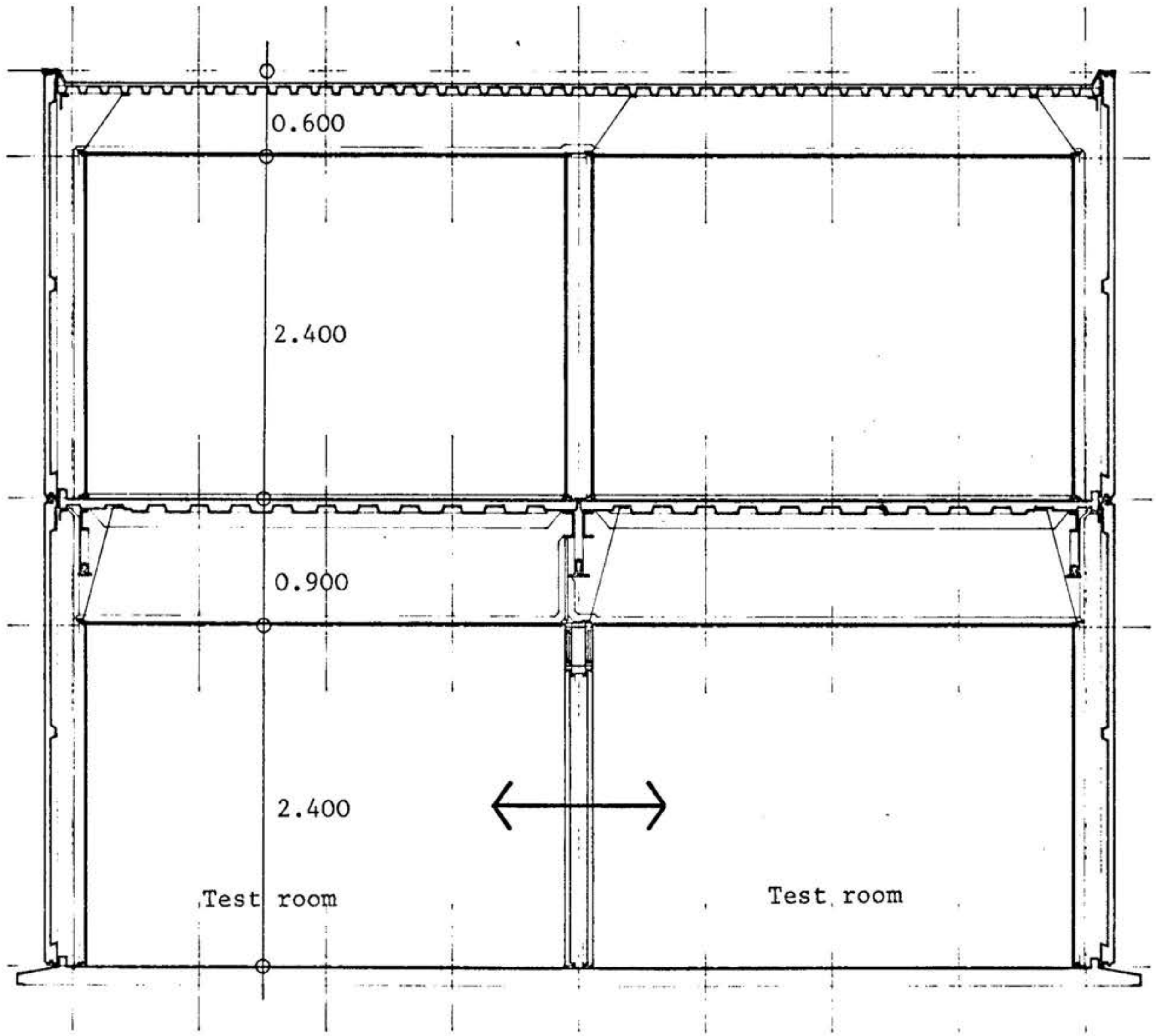
YOUNG, R.W. Revision of the Speech Privacy Calculation. Journal of the Acoustical Society of America. 38. 524-30. 1965.

YOUNG, R.W. Single-Number Criteria for Room Noise. Journal of the Acoustical Society of America. 36, 2. Feb 1964.

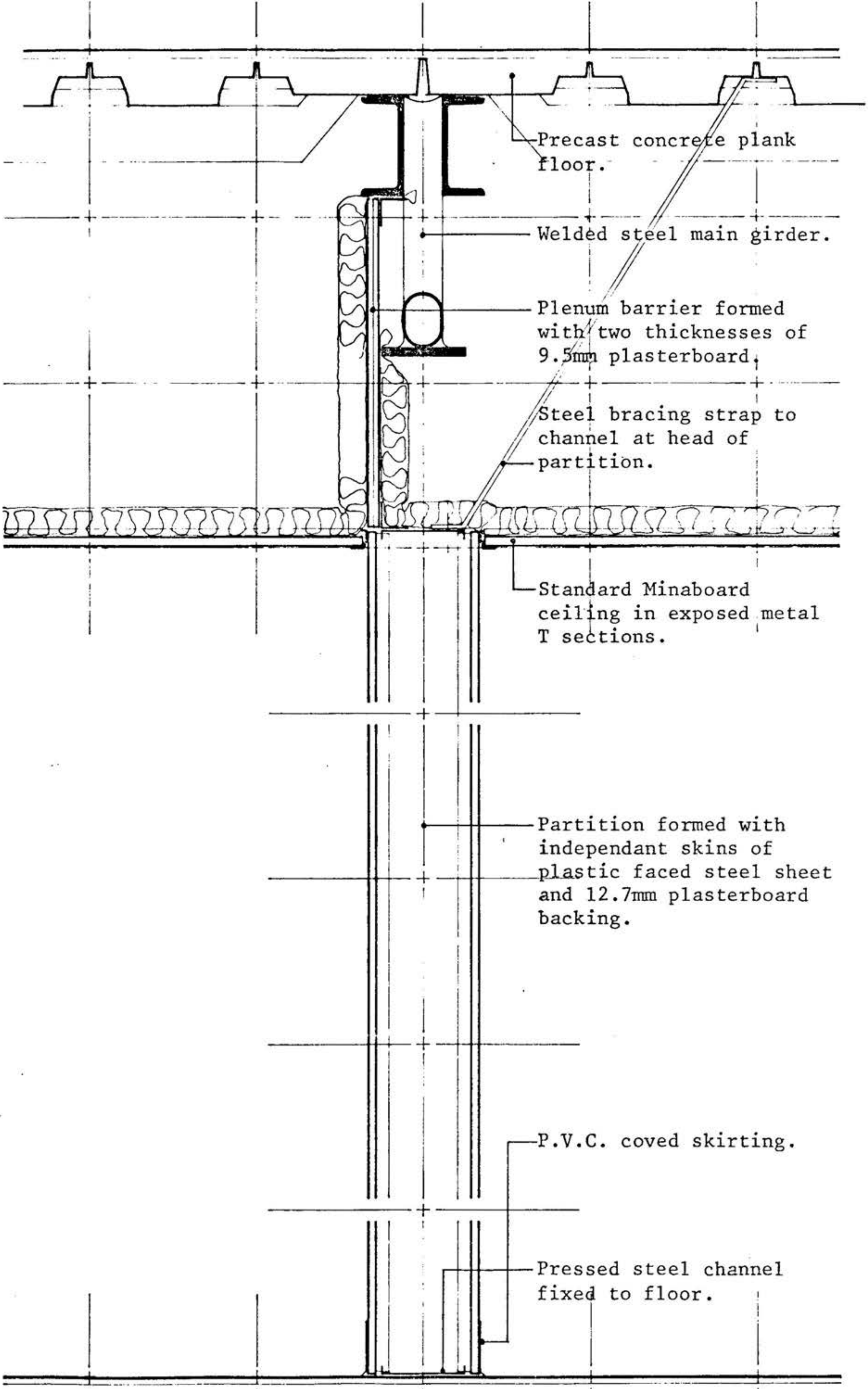
ZABOROV, V.I. Normalization of the Acoustic Reduction in Buildings. Sov. Phys. Acoust. 16. No 1. 43-45. 1970.



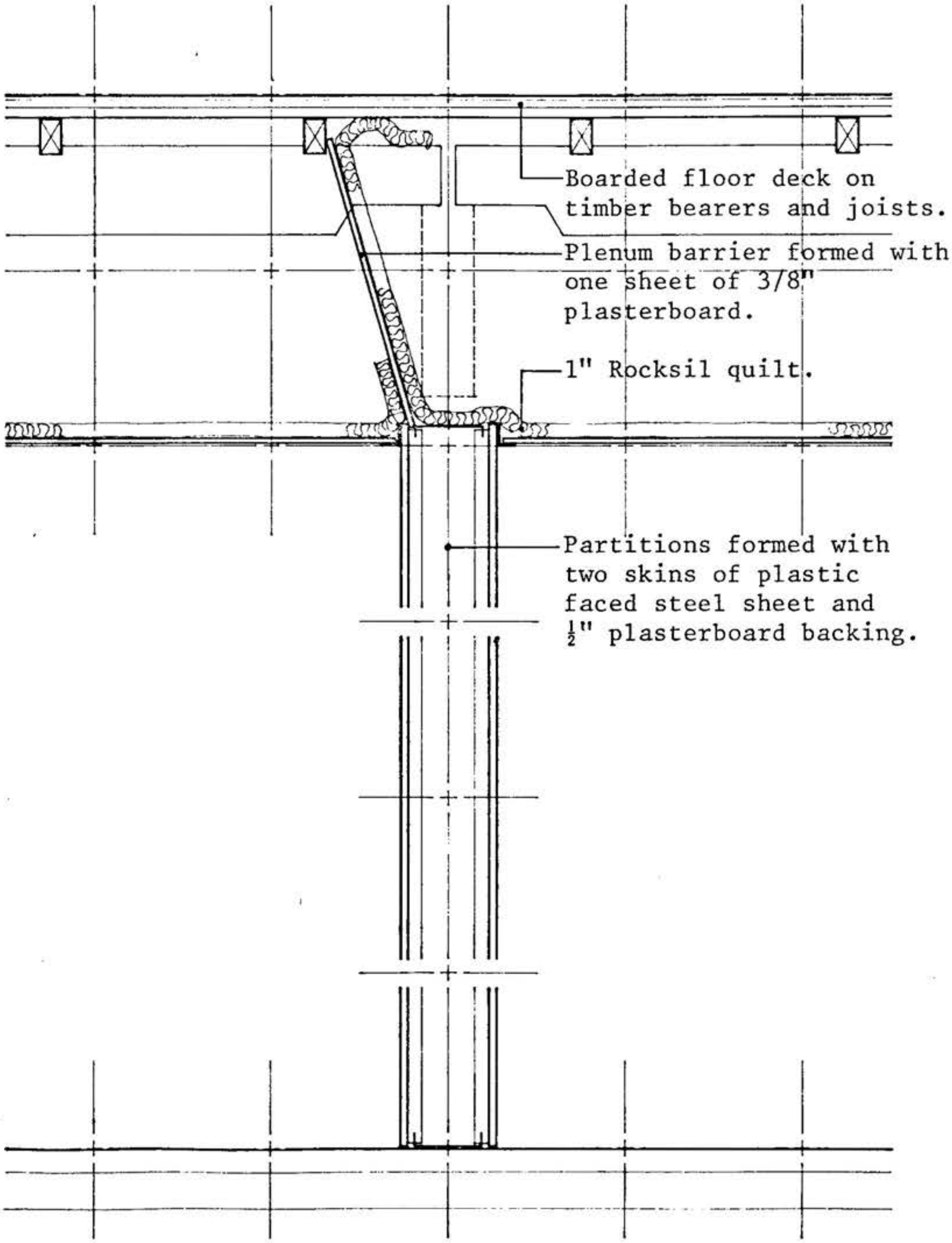
APPENDIX IVa DETAILS OF THE CLASP MK 5 TEST BUILDING AT PAISLEY. KEY PLAN. DRAWING NO. 1A. SCALE 1:50.



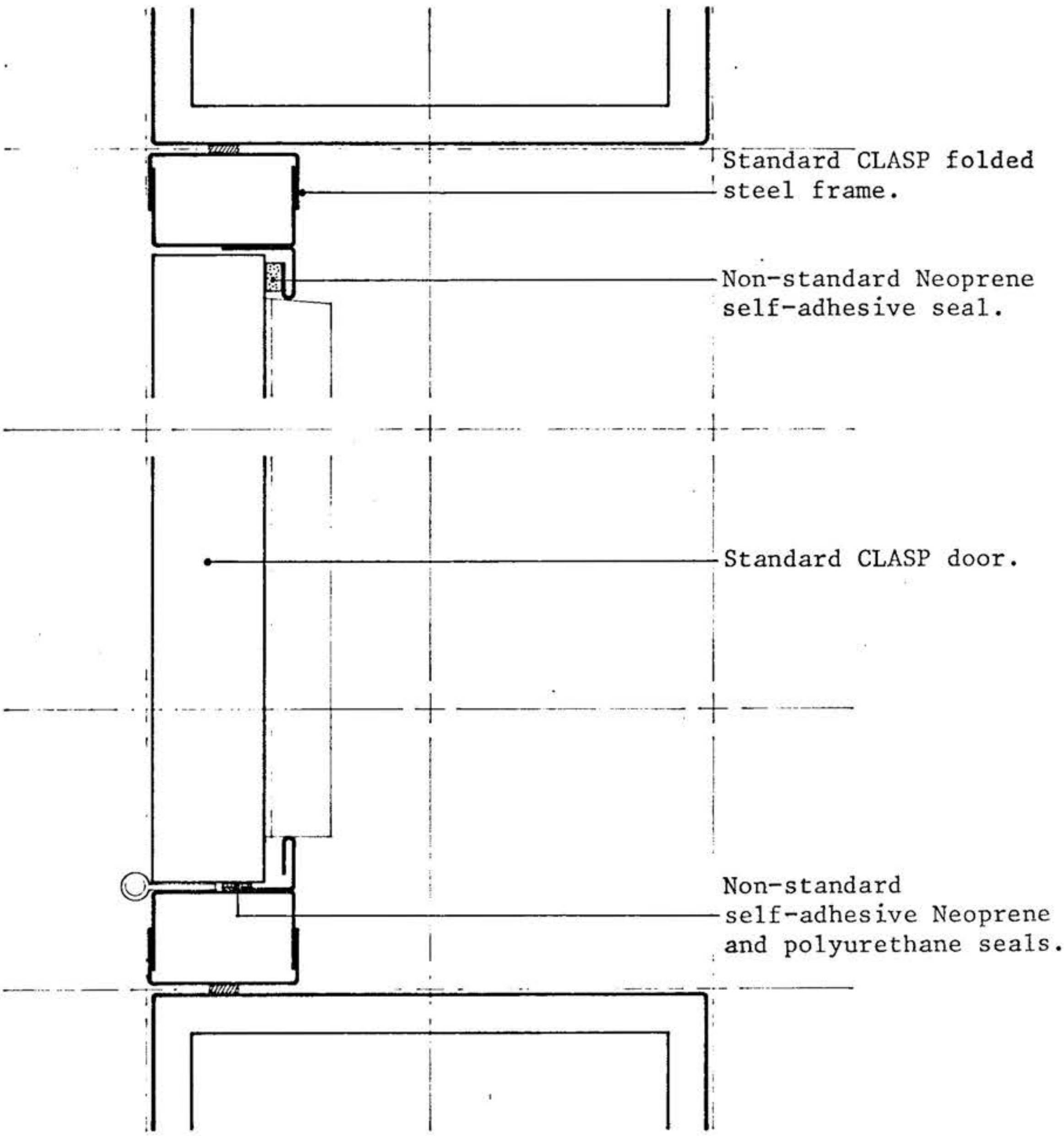
APPENDIX IVa DETAILS OF THE CLASP MK 5 TEST BUILDING AT PAISLEY. DRAWING NO 1B. SECTION A - A. SCALE 1:50



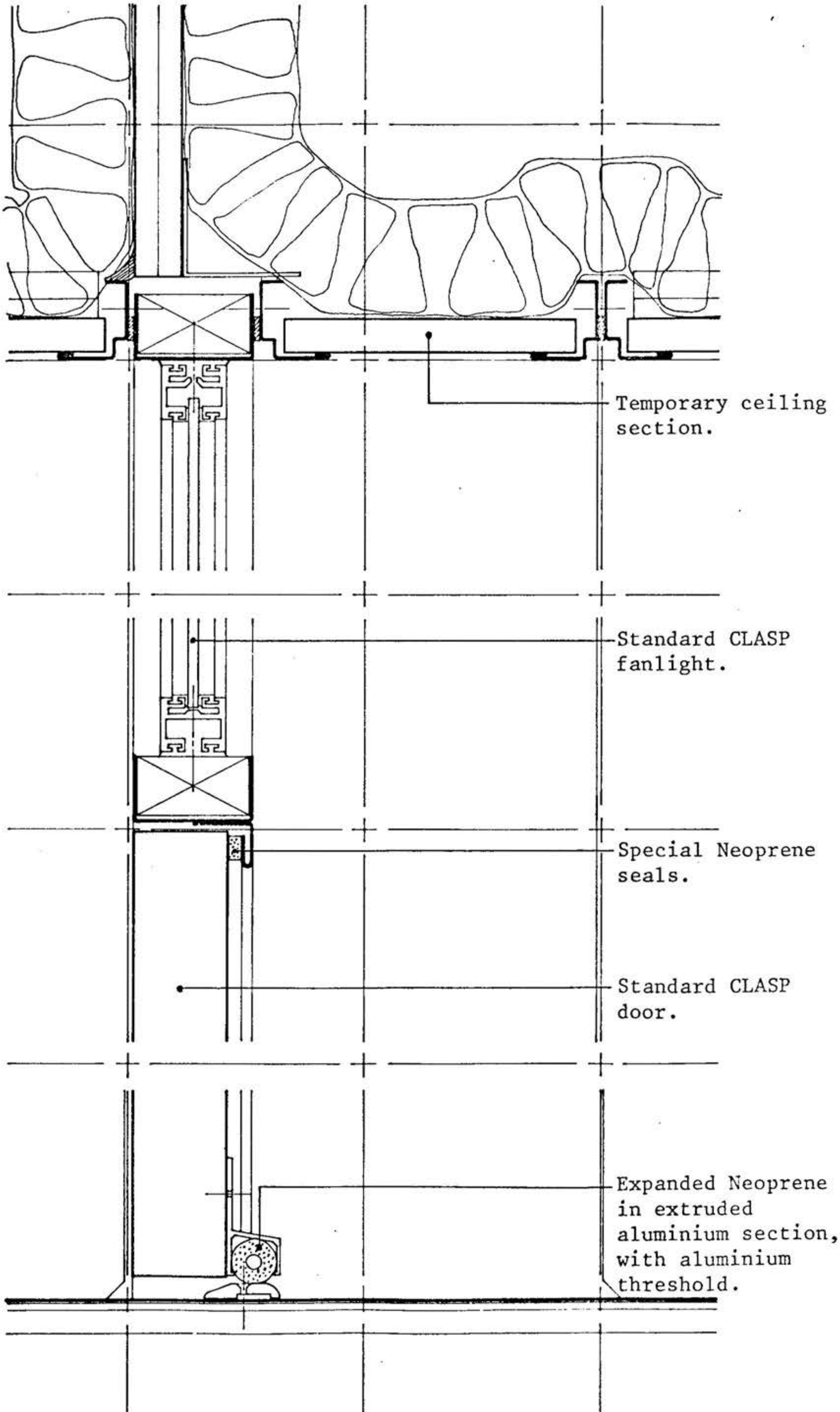
APPENDIX IVa JUNCTION OF PARTITION AND PLENUM BARRIER (Plenum barrier removed for Test B1, fitted for Test B2).
DRAWING NO. 2. SCALE 1;10



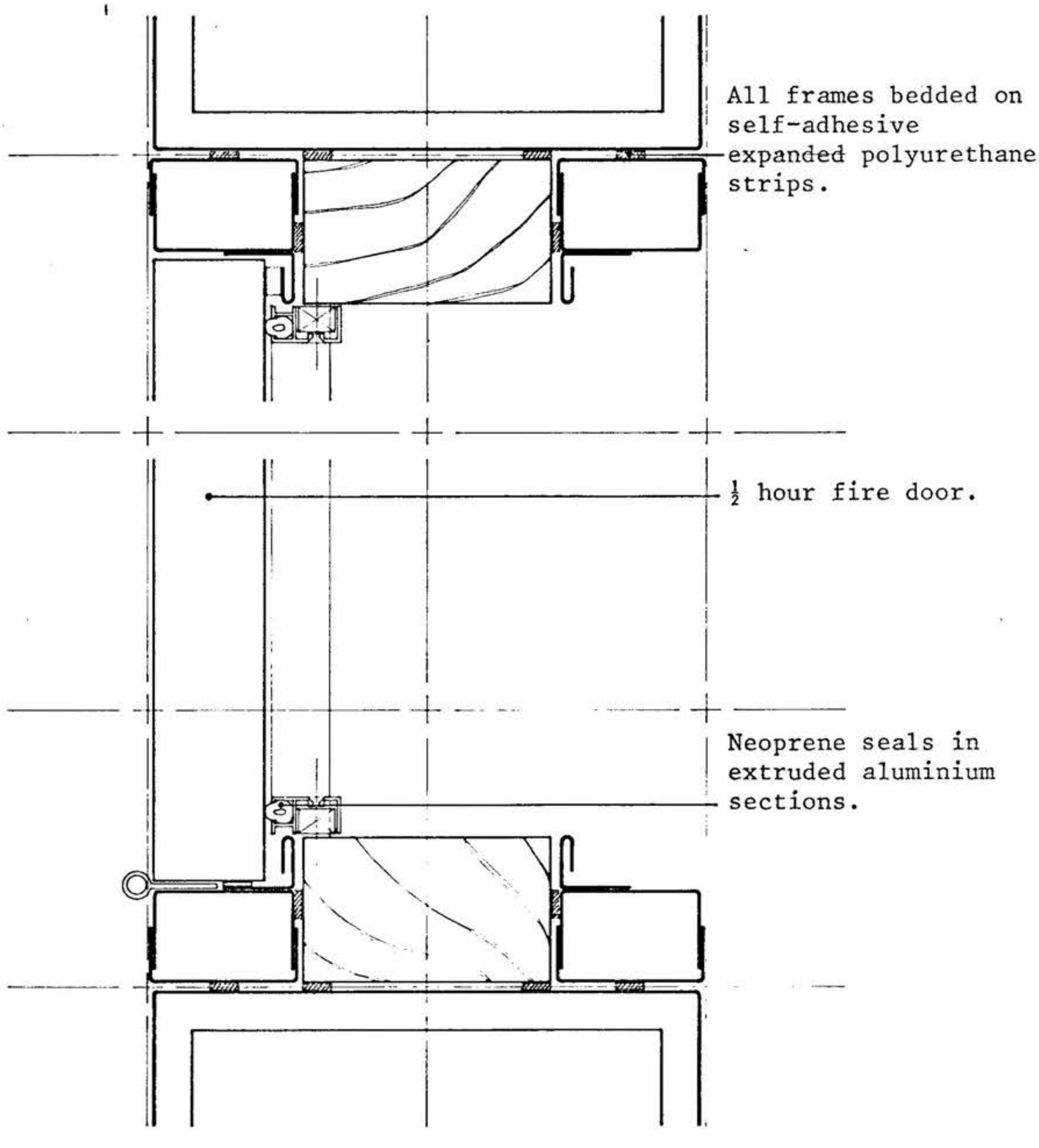
APPENDIX IVa SECTION THROUGH CLASP MK 4B PARTITION AND PLENUM BARRIER, AS IN FIELD TESTS, SERIES NOS. A1-8.
DRAWING NO 2B. SCALE 1" = 1'.



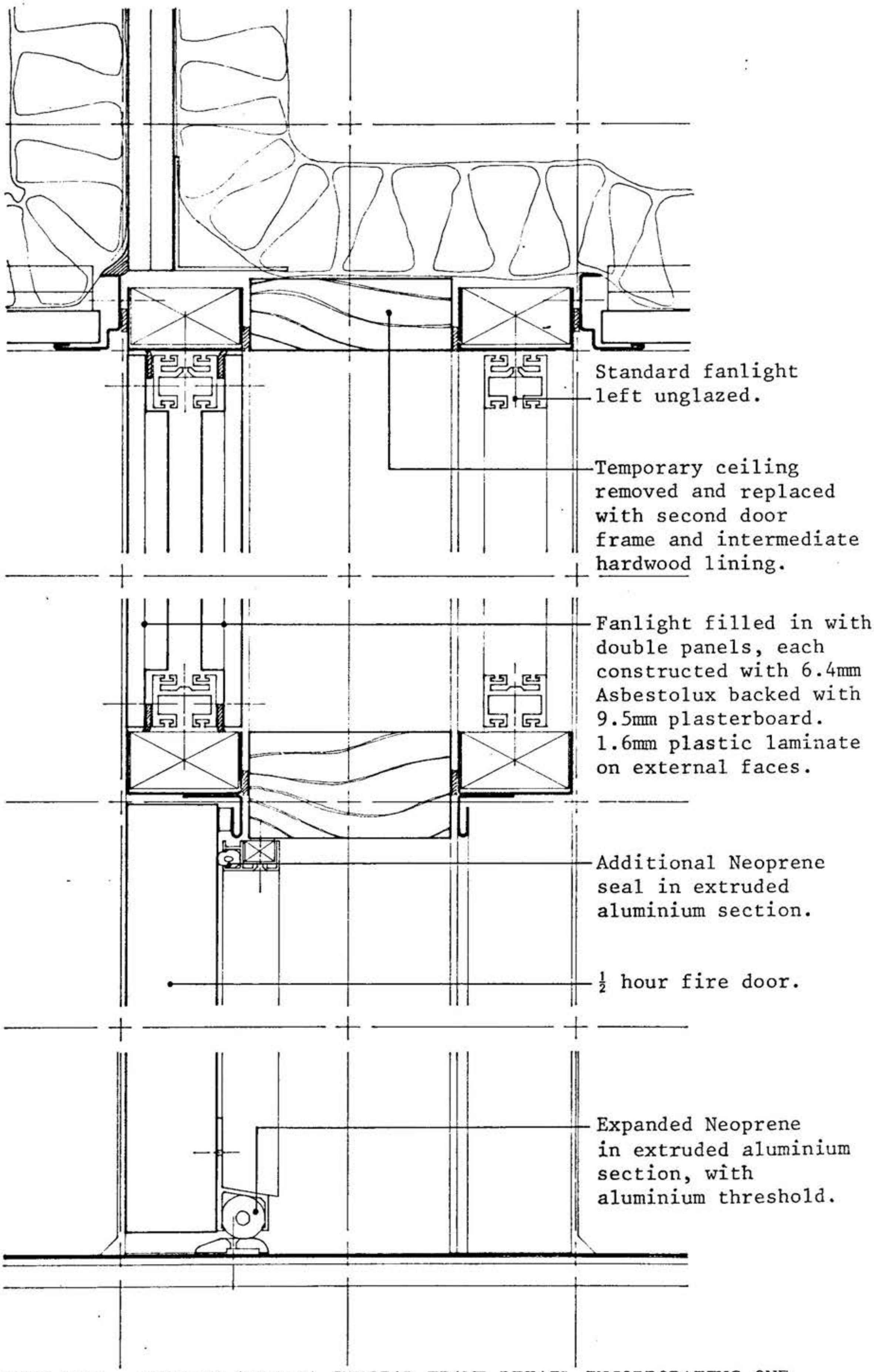
APPENDIX IVa PLAN OF STANDARD CLASP DOORSET. TEST B3. DRAWING NO. 3A.
SCALE 1:2.5



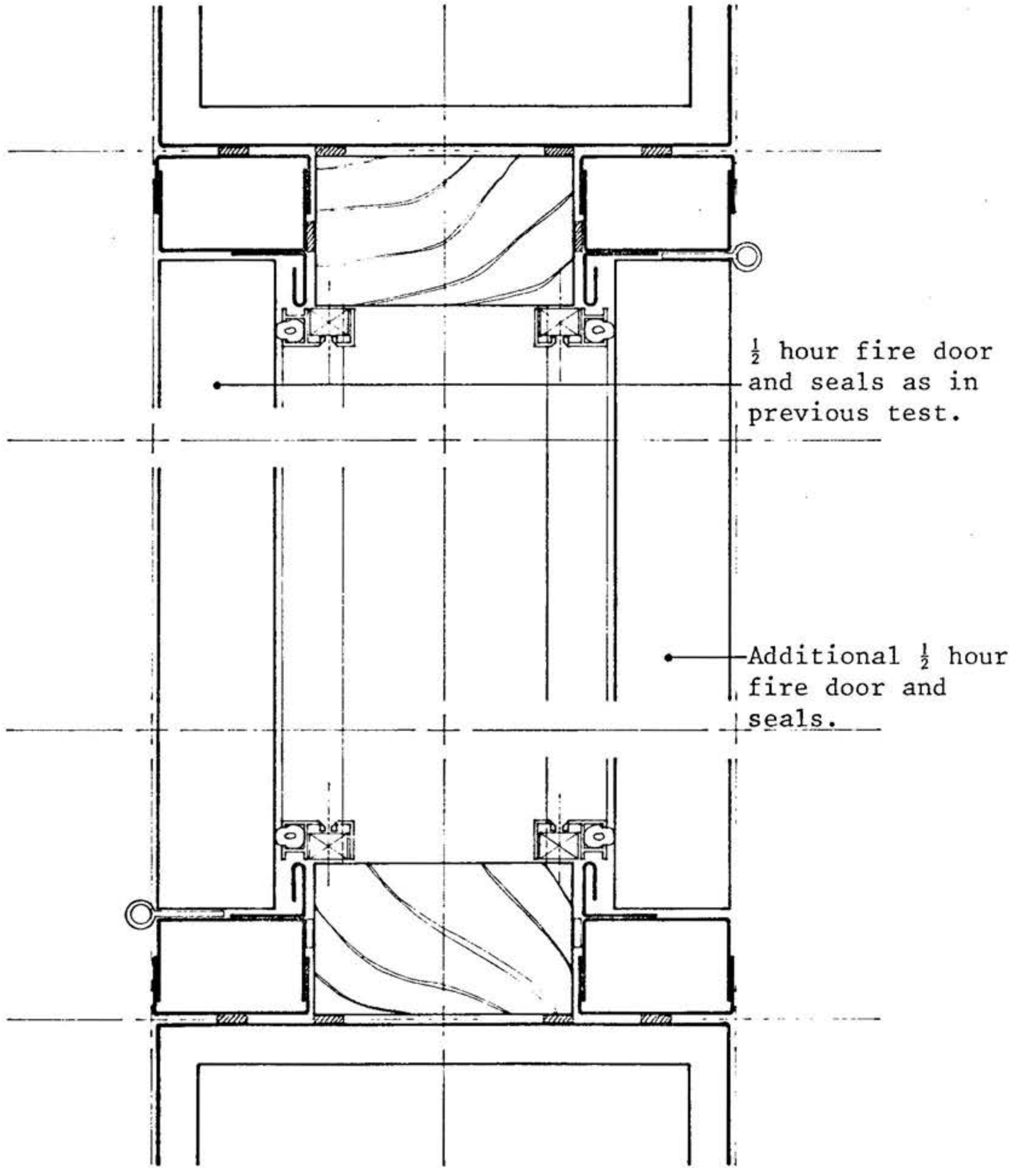
APPENDIX IVa SECTION THROUGH STANDARD CLASP DOORSET. TEST B3.
DRAWING NO. 3B. SCALE 1:2.5



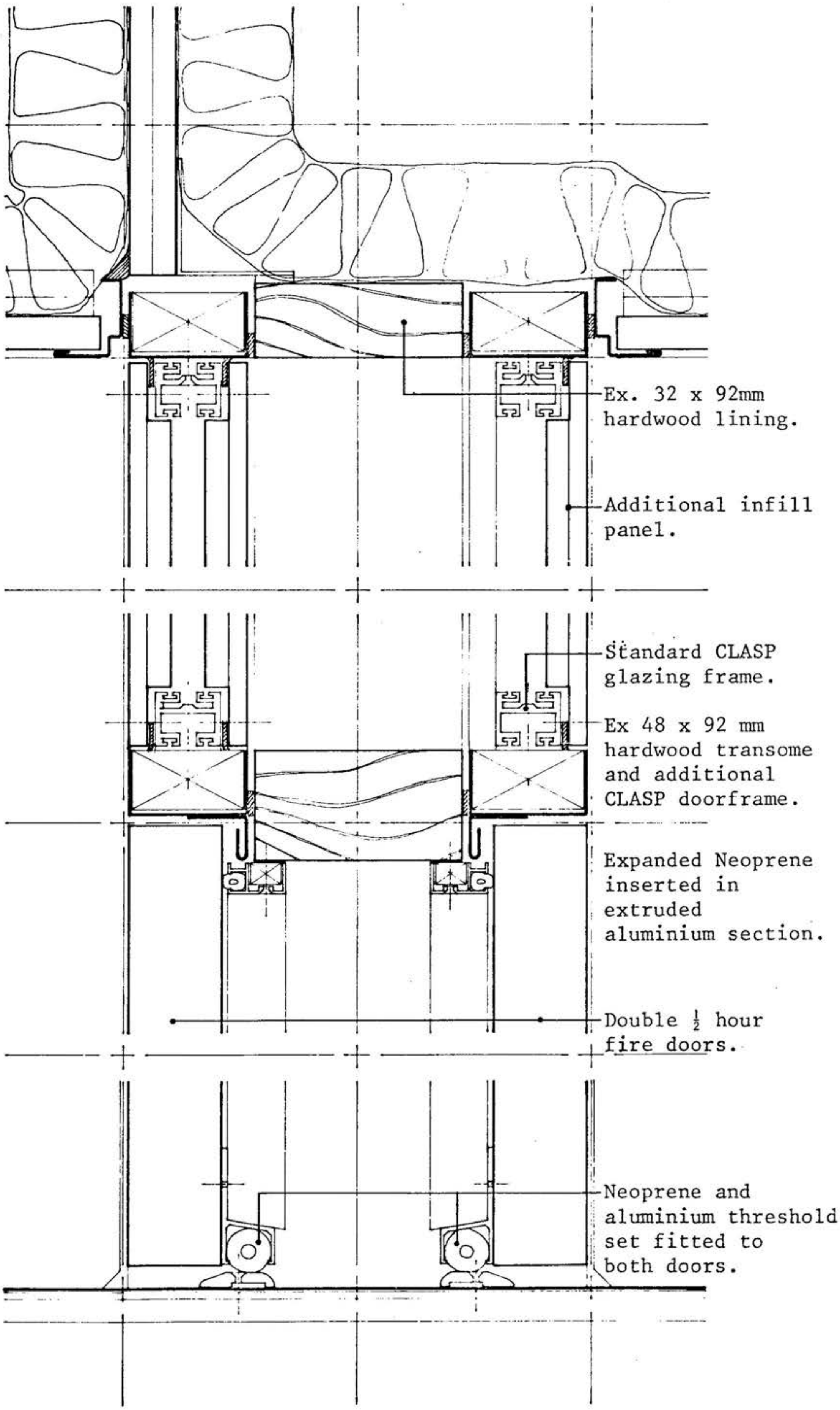
APPENDIX IVa PLAN OF SPECIAL FRAME INCORPORATING A SINGLE ½ HOUR FIRE DOOR. TEST B4. DRAWING NO. 4A. SCALE 1:2.5



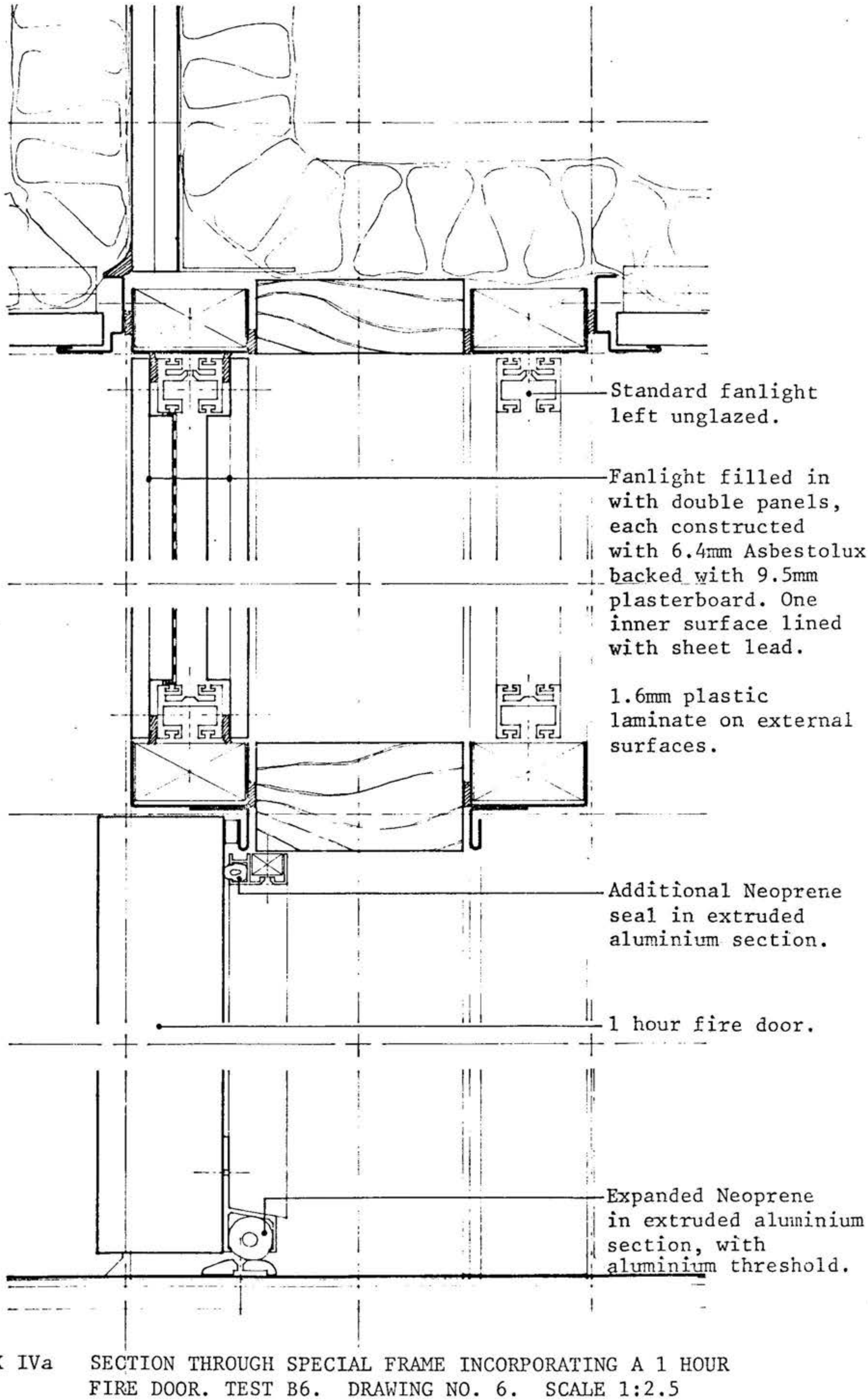
APPENDIX IVa   SECTION SHOWING SPECIAL FRAME DETAIL INCORPORATING ONE ½ HOUR FIRE DOOR. TEST B4. DRAWING NO. 4B. SCALE 1:2.5



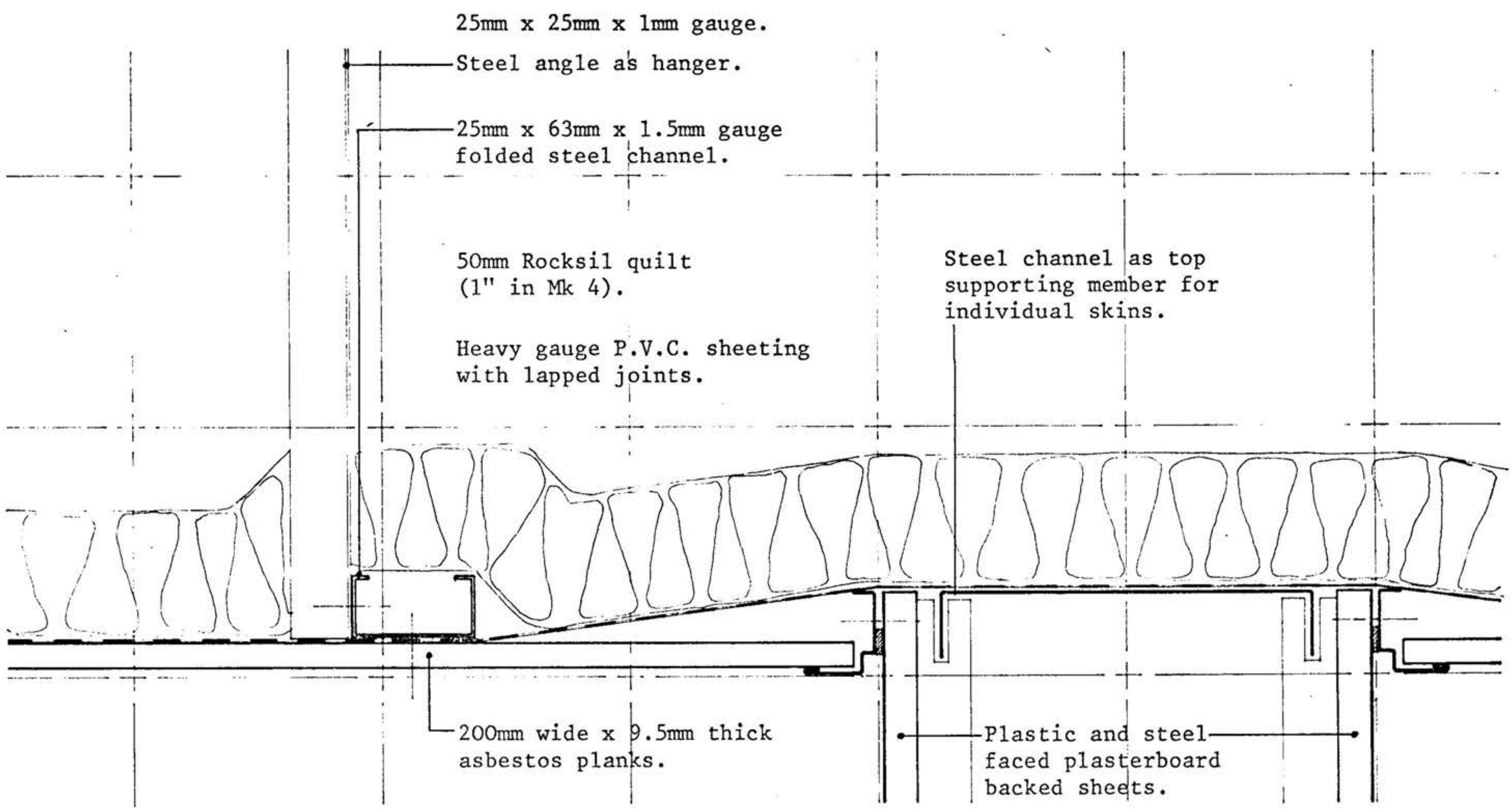
APPENDIX IVa PLAN OF SPECIAL FRAME INCORPORATING DOUBLE ½ HOUR FIRE DOORS. TEST B5. DRAWING NO. 5A. SCALE 1:2.5



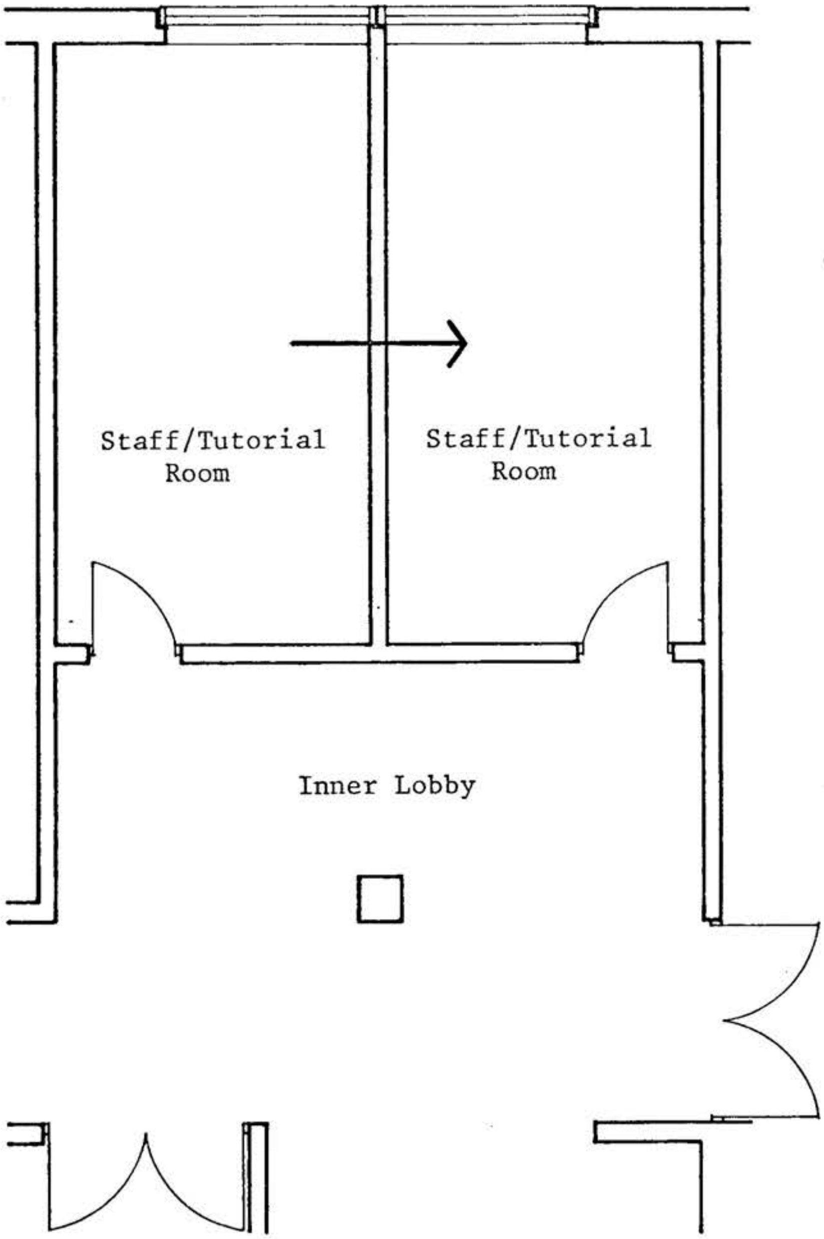
APPENDIX IVa DETAILS OF SPECIAL FRAME ASSEMBLY INCORPORATING DOUBLE ½ HOUR FIRE DOORS. TEST B5.
DRAWING NO. 5B. SCALE 1:2.5



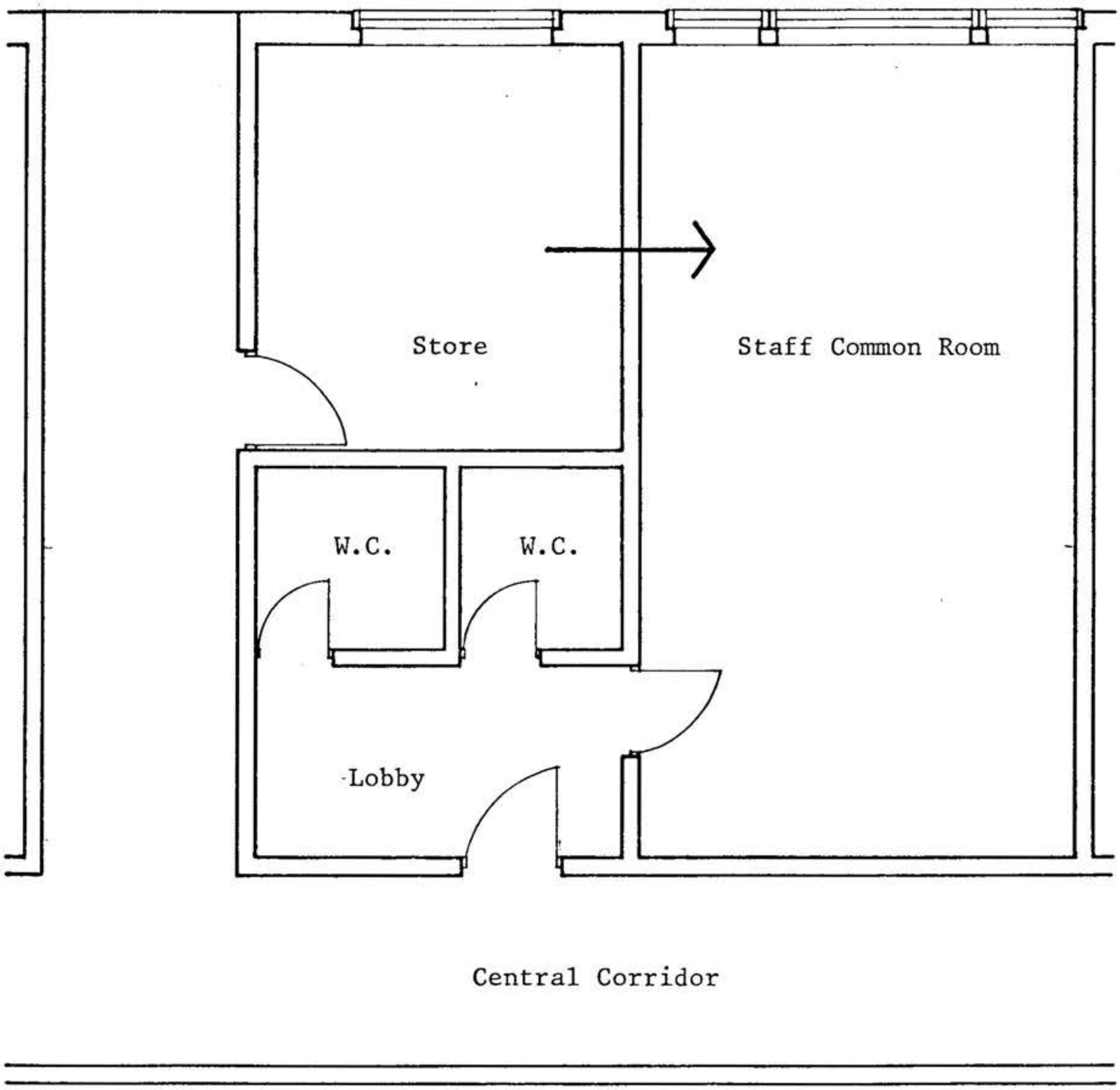
APPENDIX IVa SECTION THROUGH SPECIAL FRAME INCORPORATING A 1 HOUR FIRE DOOR. TEST B6. DRAWING NO. 6. SCALE 1:2.5



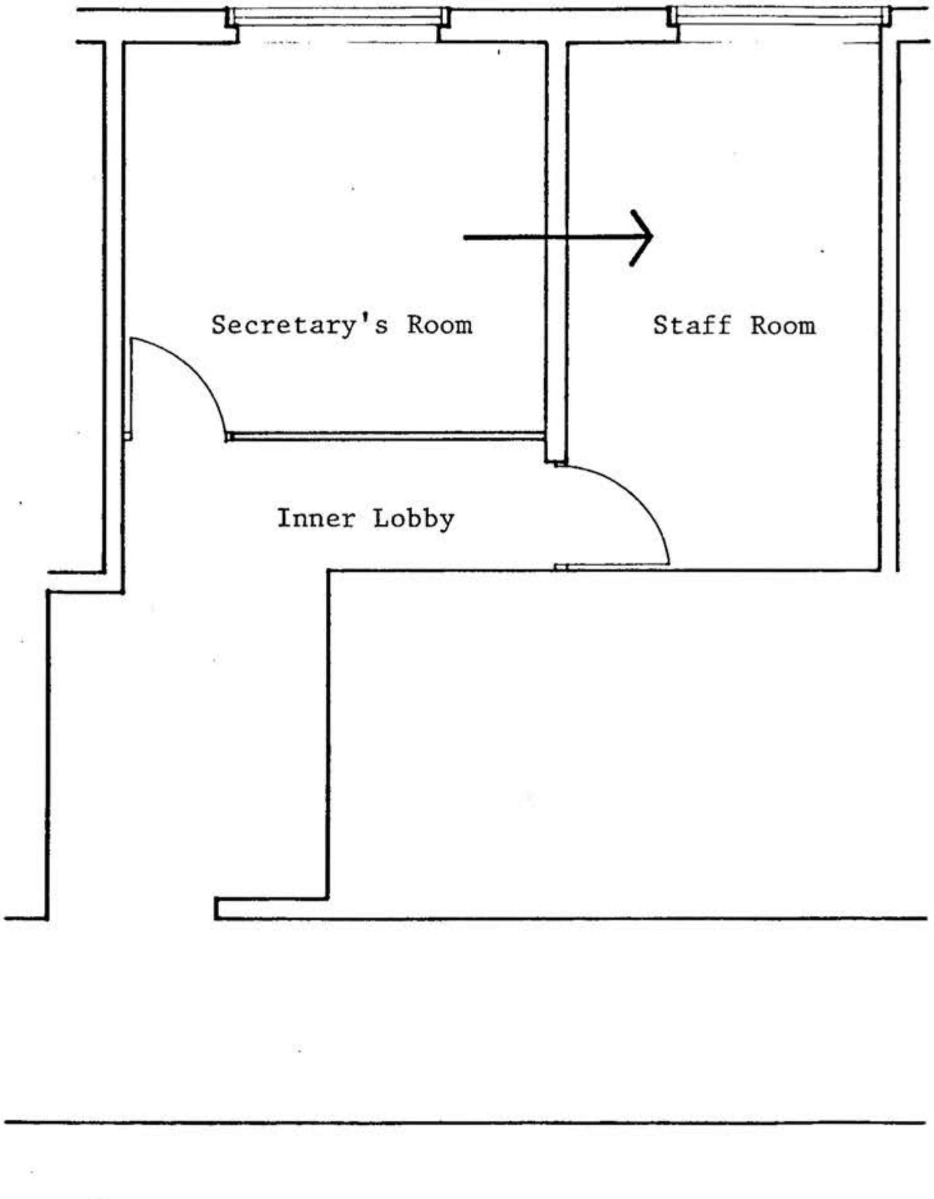
APPENDIX IVa SECTION AT JUNCTION OF ASBESTOS PLANK CEILING AND TOP OF PARTITION. TEST B7.
DRAWING NO. 7. SCALE 1:2.5



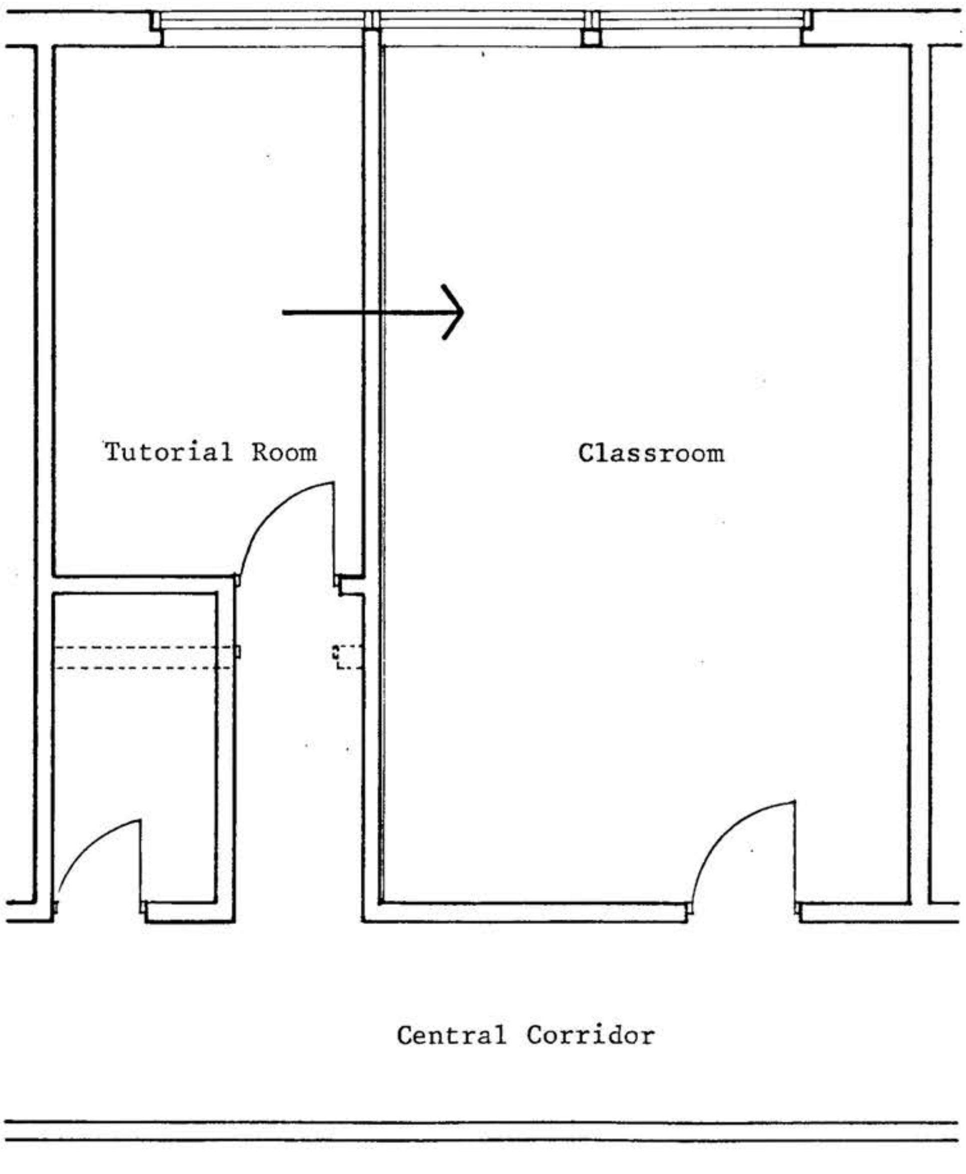
APPENDIX IVa LOCATION OF TEST NO. A1.
ROSS HIGH SCHOOL, TRANENT. SCALE 3/16" = 1'.



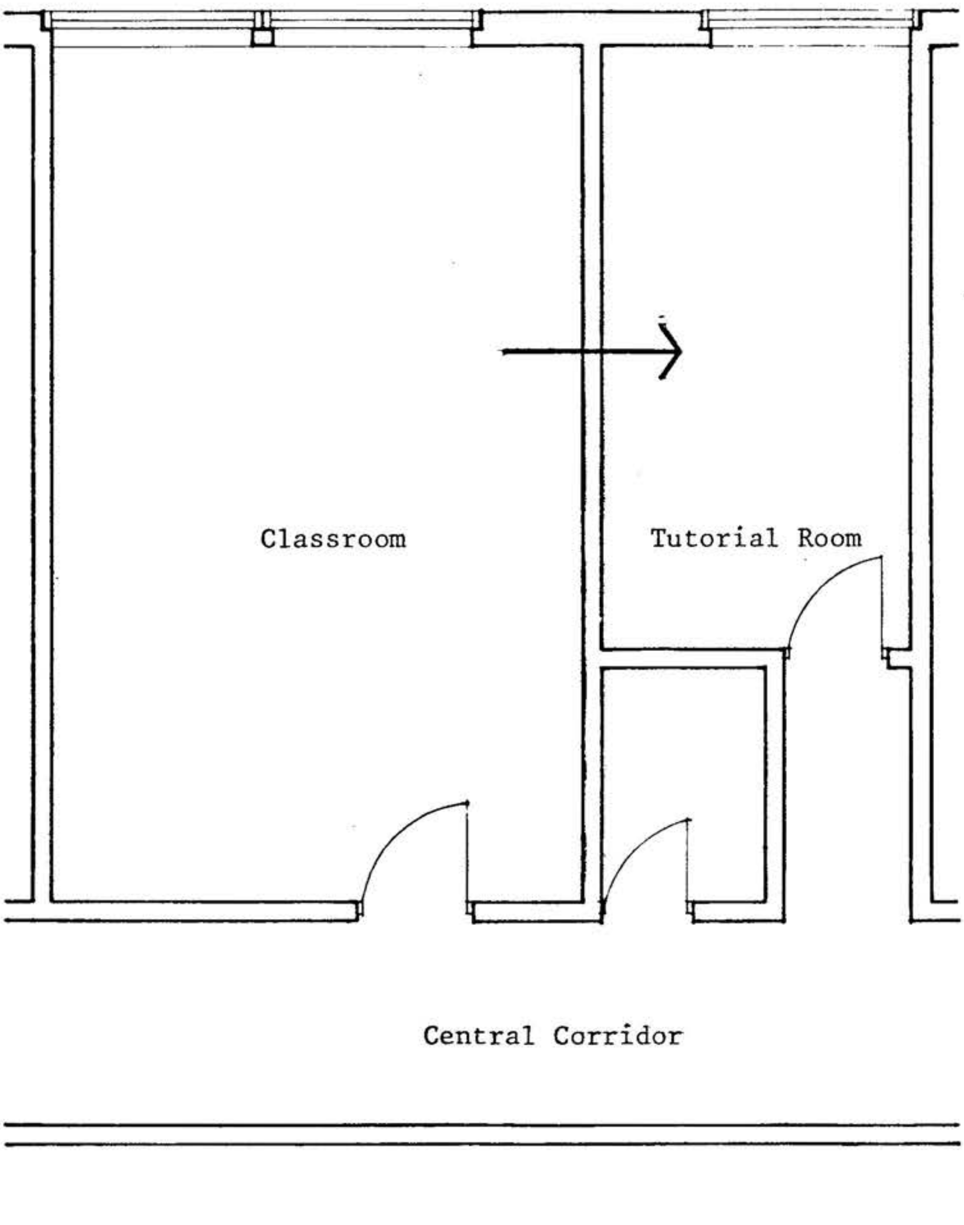
APPENDIX IVa LOCATION OF TEST NO. A2.
ROSS HIGH SCHOOL, TRANENT. SCALE 3/16" = 1'.



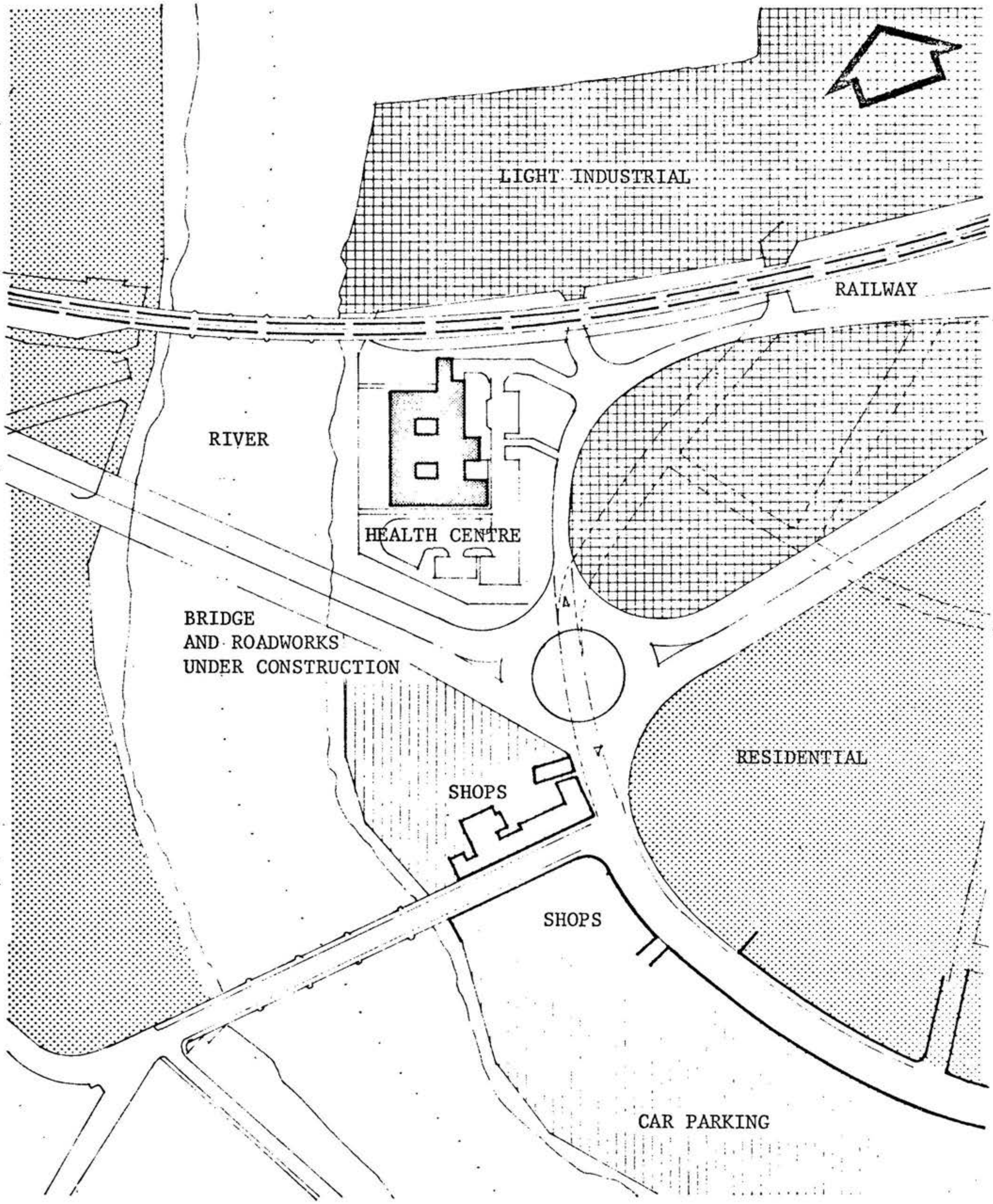
APPENDIX IVa LOCATION OF TEST NO. A3.
ROSS HIGH SCHOOL, TRANENT. SCALE 3/16" = 1'.



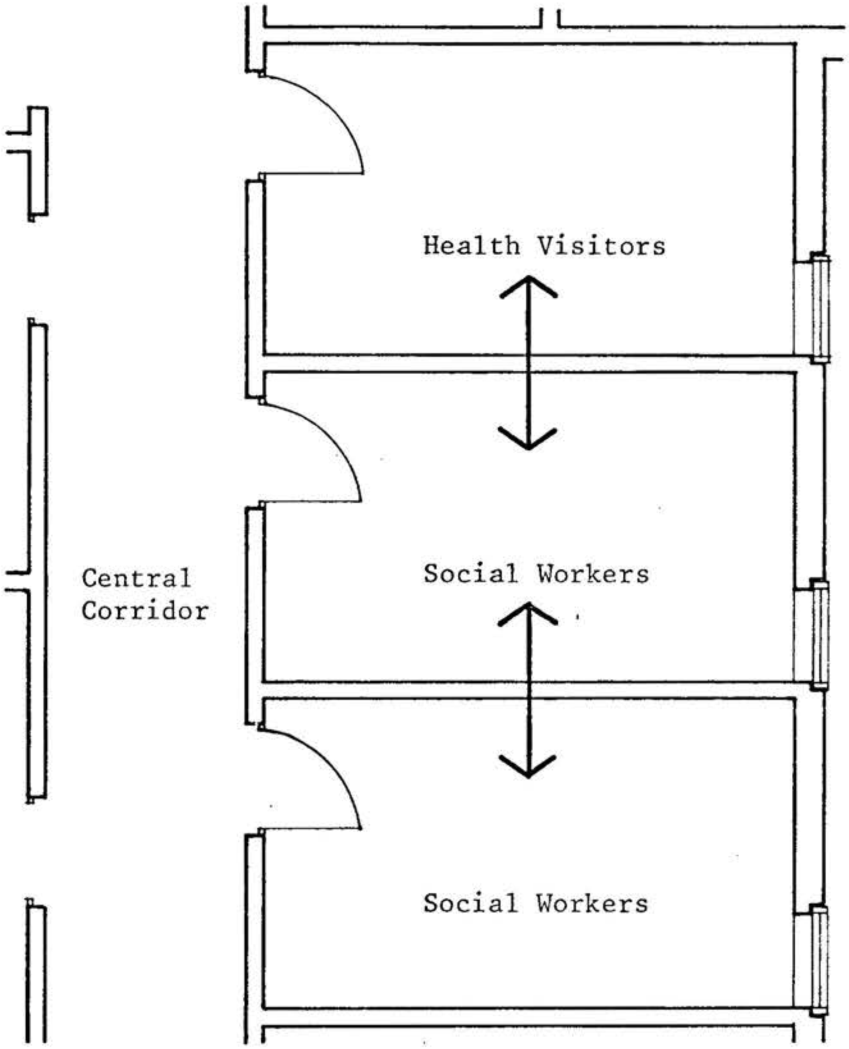
APPENDIX IVa LOCATION OF TESTS NOS. A4 AND 5.
KNOX ACADEMY, HADDINGTON. SCALE 3/16" = 1'.



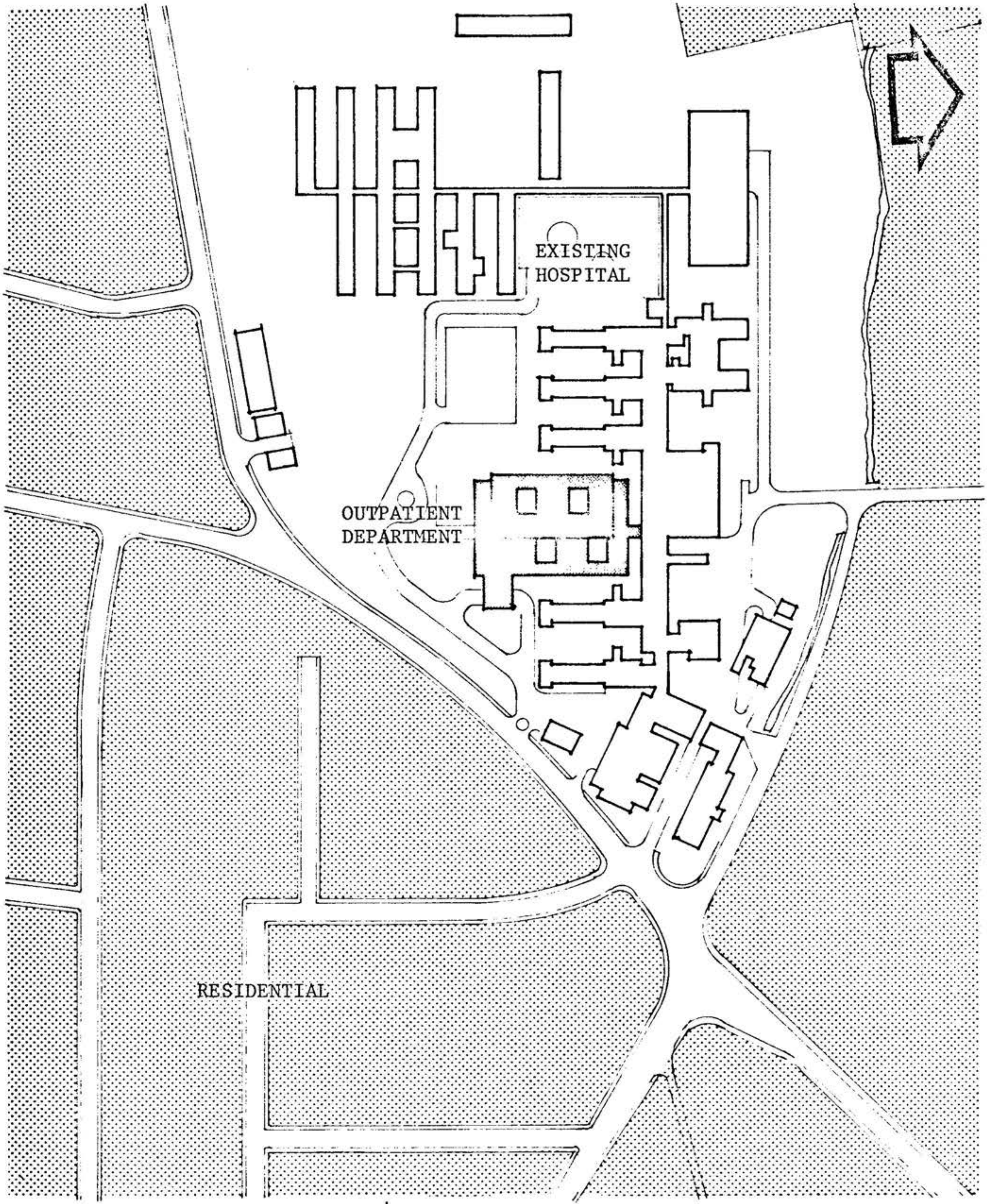
APPENDIX IVa LOCATION OF TEST NO A6.
KNOX ACADEMY, HADDINGTON. SCALE 3/16" = 1'.



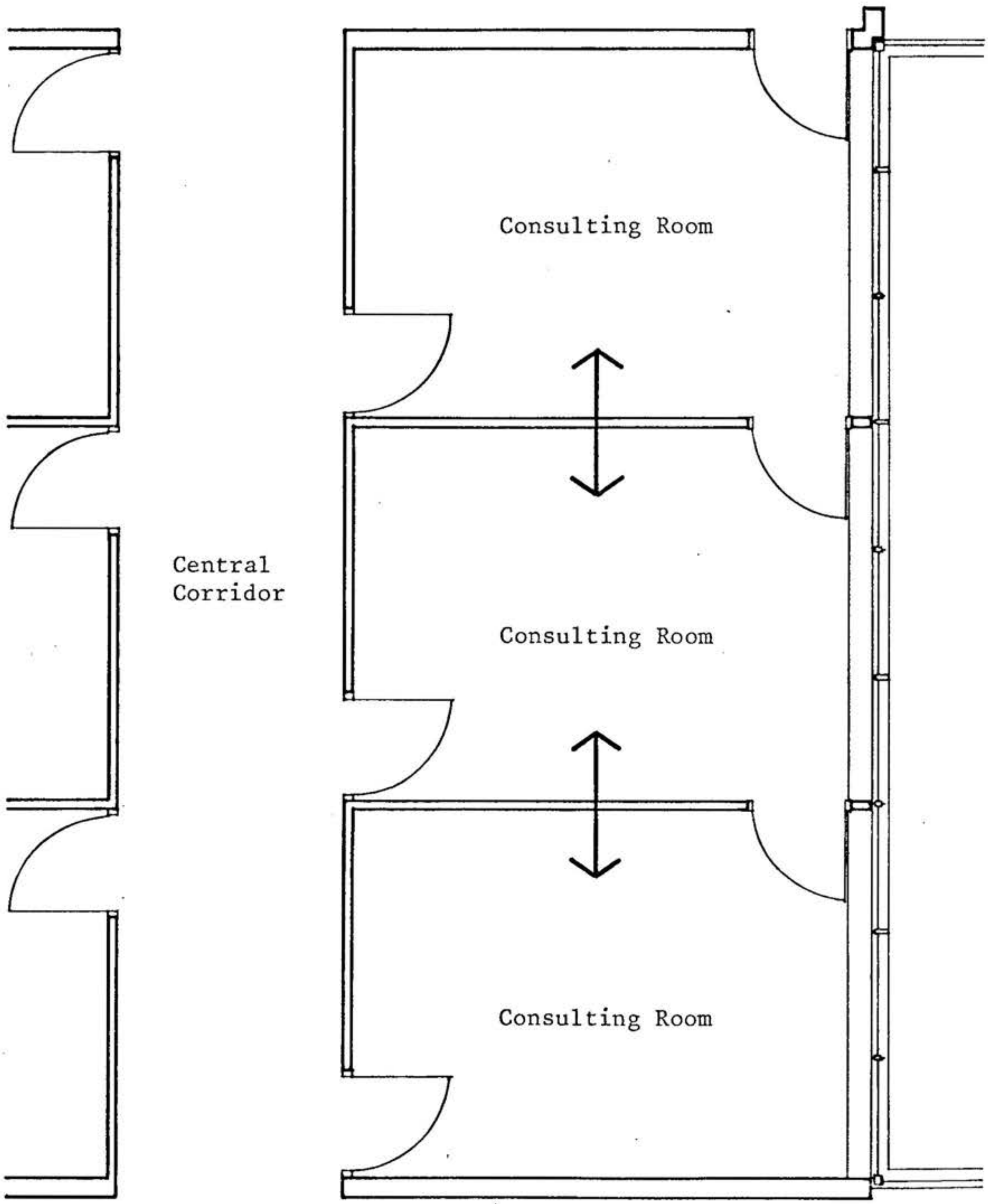
HEALTH CENTRE - DUMBARTON
BLOCK PLAN SHOWING GENERAL SURROUNDINGS.



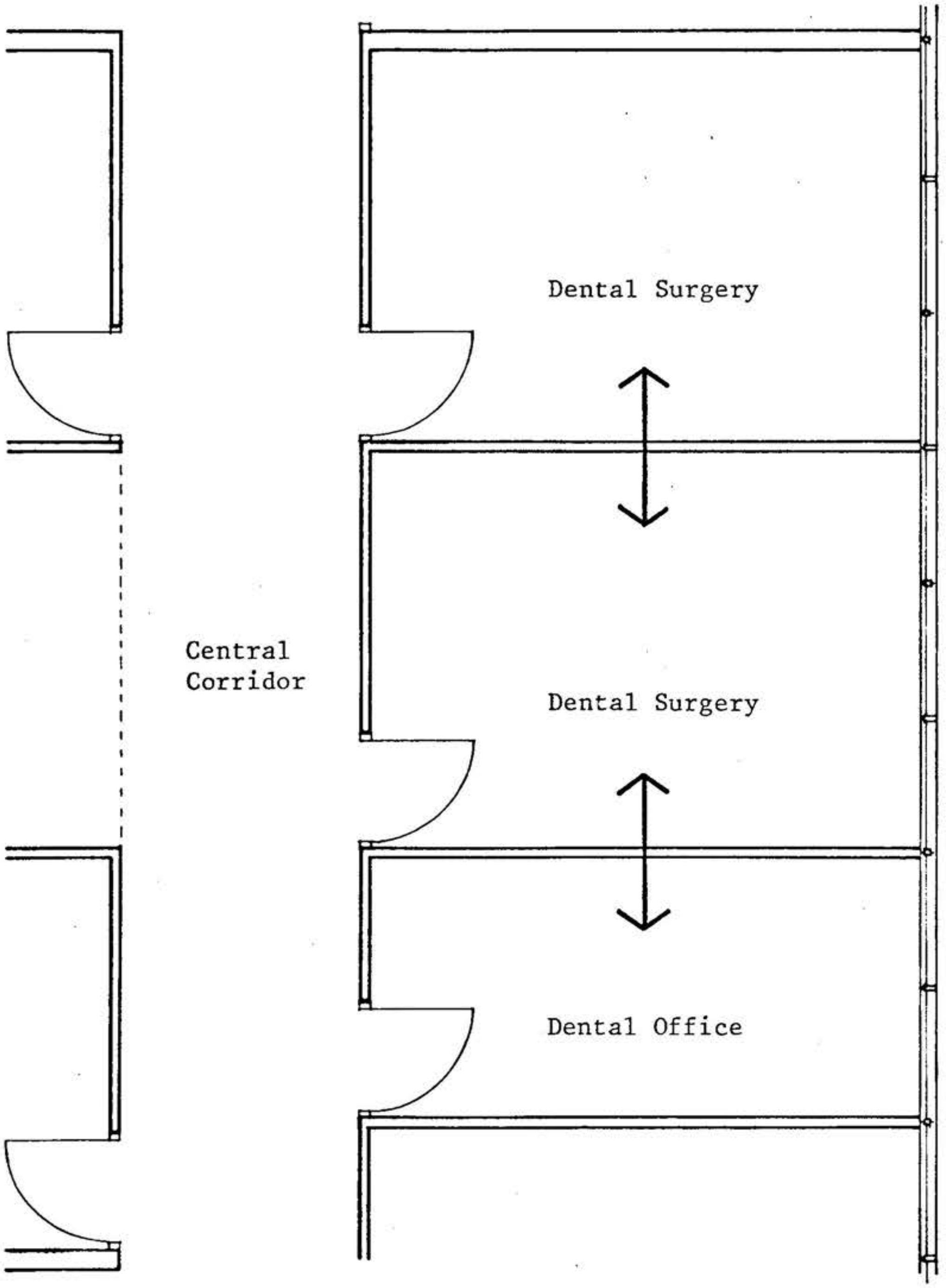
APPENDIX IVa LOCATION OF TESTS NOS. A7 AND 8.
HEALTH CENTRE, DUMBARTON. SCALE 3/16" = 1'.



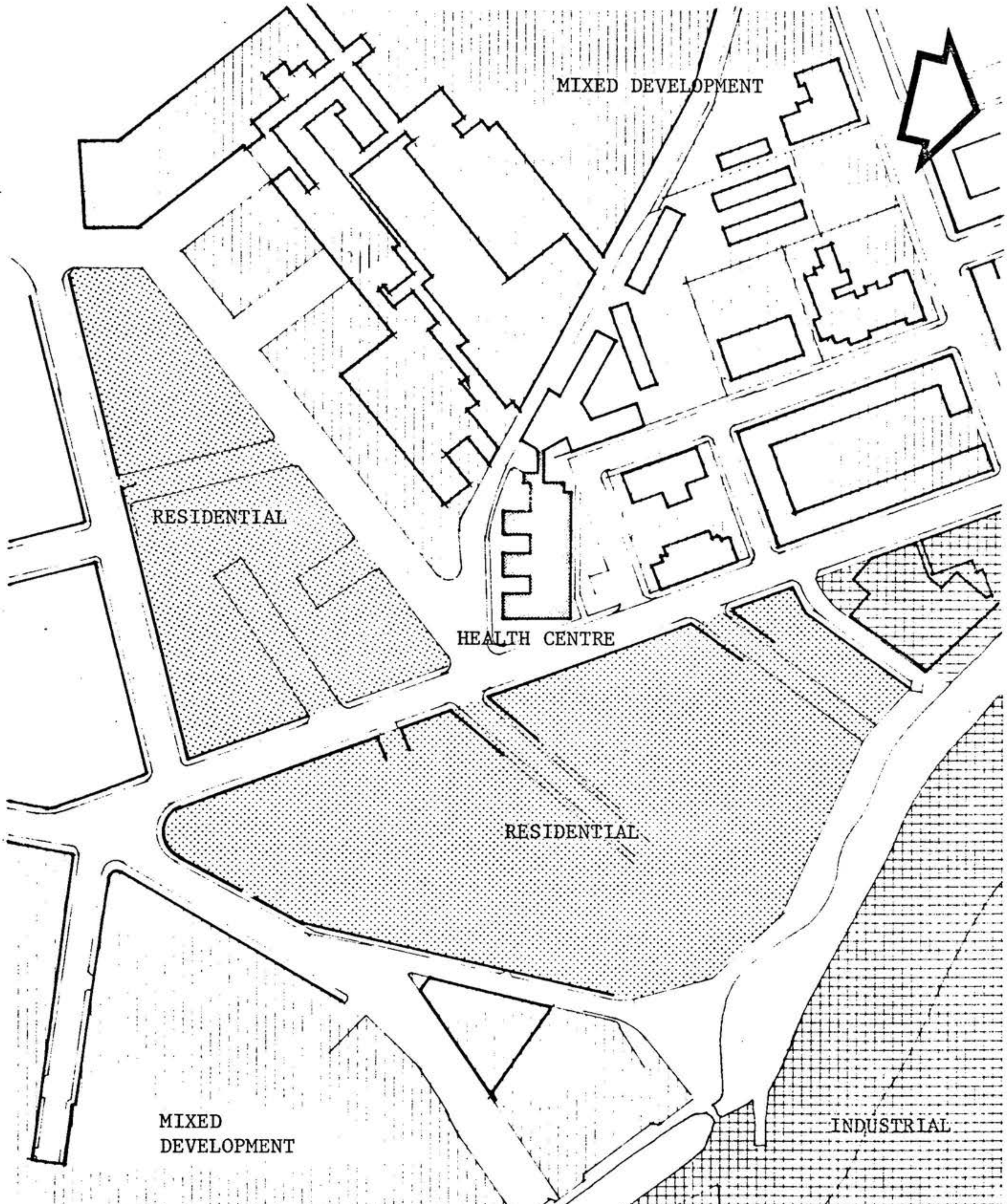
OUTPATIENT DEPARTMENT - FALKIRK ROYAL INFIRMARY
BLOCK PLAN SHOWING GENERAL SURROUNDINGS.



APPENDIX IVa TYPICAL CONSULTING ROOM SUITE USED FOR TEST SERIES C. OUTPATIENT DEPARTMENT, FALKIRK ROYAL INFIRMARY. SCALE 3/16" = 1'.



APPENDIX IVa DENTAL SUITE USED FOR TEST SERIES C.
OUTPATIENT DEPARTMENT, FALKIRK ROYAL INFIRMARY. SCALE 3/16" = 1'.



HEALTH CENTRE - WOODSIDE, GLASGOW
BLOCK PLAN SHOWING GENERAL SURROUNDINGS.